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The New Ganz System of Electric Canal Haulage.

By G. SZASZ.

EARLY last year the Committee appointed in connection with the Teltow Canal (a scheme designed to connect the rivers Havel and Spree) invited a public prize-competition, the purpose of which was to enable the members to adopt from the various systems by which applicants tried to solve the difficult question of an electric canal-haulage service one which, under existing conditions, would be the most suitable for the working of a traffic of nearly 4,500,000 tons per annum on a canal of about 37 kilometres in length.

From the fact that it was necessary to invite a competition with prizes amounting to 12,000 marks (£600) as award for the best electric haulage system, two conclusions may be drawn: (1) That the systems hitherto known were not recognised as an adequate solution of the question; and (2) that many advantages were anticipated from the application of electricity, as compared with the present method of freight traffic on canals.

None of the many systems for electric canal haulage which have sprung up during the last few years have enjoyed universal recognition. The majority of them have not got beyond an experimental stage, and the difficulties connected therewith hardly allow of conclusions being drawn with regard to a forthcoming more general application. It must be confessed also that the results obtained from the regular electric traffic working in France and Belgium during the last few years have not come up to the general standpoint of working and economy attached to the application of electricity for canal-haulage service.

Twenty applicants took part in the prize competition of the Teltow Canal, but many of the schemes submitted were already known. Three of the schemes received awards, as they appeared to be most suitable under the existing conditions; and two others, which, owing to various details, were found to be of particular interest, the jury decided to purchase. One of these was the system of Messrs. Ganz & Co., of Budapest, which, owing to the fact that it was worked out on a different basis, represented an entirely new system. Apart from the technical execution of this system, it has the advantage of presenting numerous economical features not to be found in other systems, as may be seen from comparison with the other schemes which have been given awards. The Ganz system being therefore of interest to a wider circle of readers, we propose to give a description of its main characteristics.

In order to place this system in its proper light, we would refer in a few words to certain features attaching to the tow-locomotive hitherto known. Up to the present, a locomotive running along the tow-path without any permanent way—in fact, an electric Automobile—to which barges are attached, has been the most general means of traction. This kind of conveyance, although obviating the necessity of a permanent way, nevertheless requires a very good tow-path. This has to be kept continuously in good condition if trouble in working is to be avoided and, consequently, the cost of repairs is very high. To this may be added the cost of maintenance of the locomotives themselves, which is also high owing to the continual shaking to which they are exposed on the open path. The efficiency of this means of conveyance cannot possibly be a high one, seeing that it has to surmount a considerable resistance of its own when moving on the open path. If, moreover, the fact is taken into account that the vehicle is not directed in a self-acting manner by the rails but by the car-driver himself, whose attention is continuously necessary, especially during the night, and also that, when crossing bridges,

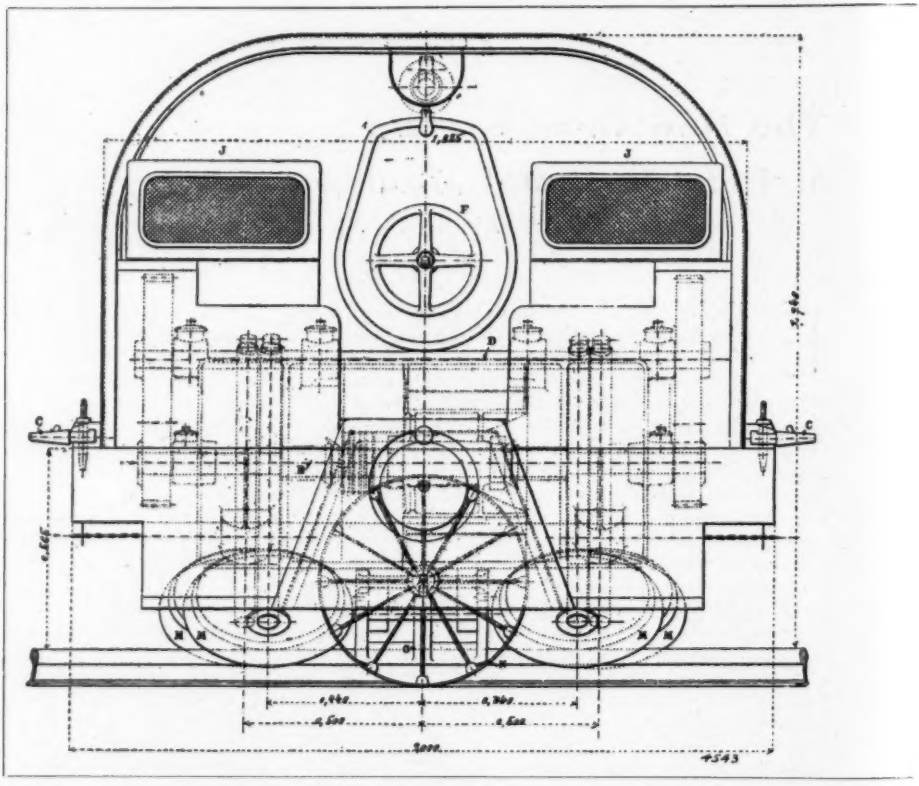


FIG. 1.—FRONT VIEW.

the service has to be discontinued, since the locomotive has to turn round the bridge necessitating the disconnection of the tow-rope; it is very apparent that this vehicle, commonly known as *le cheval électrique* can hardly be recognised as a final solution of the canal-haulage service.

disfavour of the former, seeing that, consequently, only light barge-sets could be drawn. In order to be able to draw heavy barge-sets the locomotives would have to be increased in weight and the track strengthened, both of which proceedings mean a considerable increase in cost.

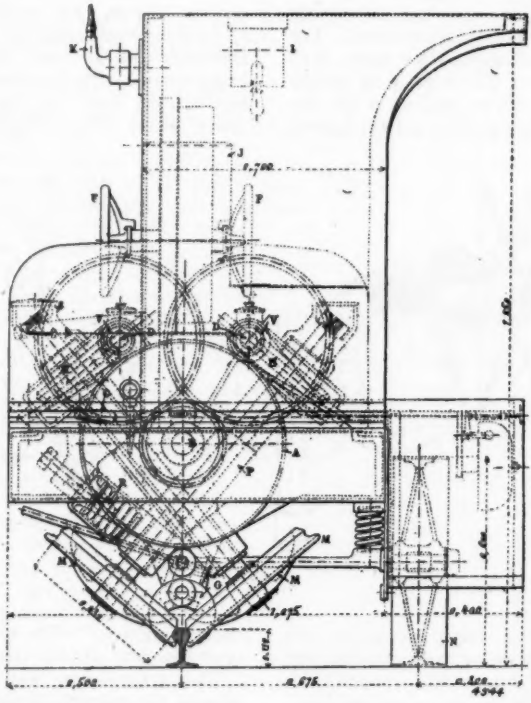


FIG. 1.—BACK VIEW.

Many of the drawbacks attaching to these tow-automobiles might be avoided by the use of a permanent way, thus changing it into an ordinary tow-locomotive. However, the great expense which would be incurred in putting down a two-railed track, in addition to the proportionally small co-efficient of adhesion, are arguments in

By the use of a monorail-track, the cost of the permanent way is materially reduced, and as, by this arrangement, very little of the weight required for the adhesion, *i.e.* about 15 per cent., will be lost, it deserves to be fully considered. This does not mean a perfect solution of the question, because it only decreases

the cost of the permanent way without rendering the use of heavy, and therefore dearer and less economical, locomotives superfluous. The question of adhesion, however, is of immense importance in canal-haulage. Experience shows that tow-resistances arise which, under ordinary circumstances, one is not prepared for. Wind, streaming water, bends, and the necessary steering may multiply the ordinary tow-resistances which are to be expected under normal conditions. For these eventualities the tractor alone is to be relied on, and therefore must ensure not only the requisite adhesion for the haulage, but the perfect safety against disturbances which might occur in such critical moments, owing to the considerable increase of the haulage-pull. Indeed, this pull, as soon as it exceeds a certain limit, endangers the stability of the tractor in almost all the tow-locomotives hitherto known. Surveying the electric towing-service field from the present-day standpoints, it may be stated that the solution of the adhesion question without any expensive auxiliary means, in conjunction with the solution of the stability question when using light locomotives, embodies a vital query for the electric-towing service. It is, perhaps, hardly necessary to add that the use of locomotives with pinions running on racked tracks cannot be regarded as an adequate solution of the adhesion question, owing to the high preliminary cost.

Led by these considerations, the firm of Messrs. Ganz & Co. took up and developed an idea for a tow-locomotive, laid before them by Engineer M. Fabre. With this locomotive two inclined pairs of axles were to be used instead of the customary two horizontal wheel-axles having two vertical wheels. On every axle there is an inclined wheel, and each pair of wheels embraces the rail-head, the wheel profile being shaped correspondingly. The locomotive runs upon one rail only, another lateral wheel being provided to back up the locomotive. This wheel runs on the open tow-path without track.

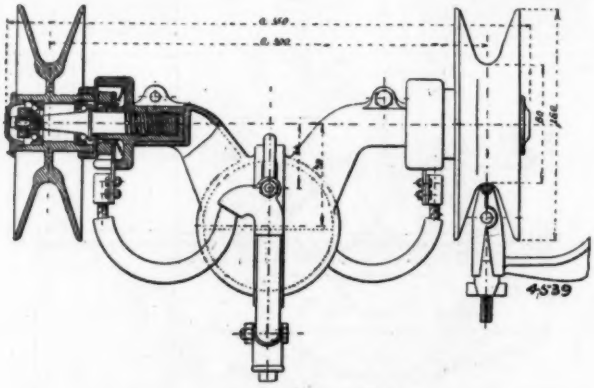


FIG. 2.

This arrangement was designed originally for the purpose of utilising the rope-pull for the increase of the adhesion as well as the stability of the locomotive in the manner described below. In the locomotive as further developed, however, the adhesion was further increased, inasmuch as the weight of the locomotive was allowed to exercise a wedging action upon the inclined axles.

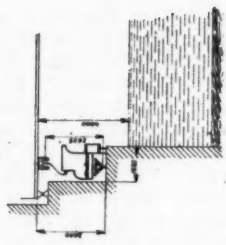
The canal-haulage system as designed by Messrs. Ganz & Co. is built up upon this new locomotive type, and in it they have endeavoured to surmount all the difficulties met with in almost all the

tractor types hitherto known. They have also effected a considerable saving in the first cost as well as in the cost of working as compared with other systems.

The fundamental qualities of this locomotive are as follows :—

1. With the use of one rail a very high co-efficiency of adhesion, and consequently a very light-weight locomotive.
2. The utilisation of the tow-rope pull for the increase of the adhesion of the locomotive.
3. Proportional increase of the stability of the locomotive according to the effort put out.

The locomotive is illustrated in Fig. 1. It rests upon one rail only, which differs little in shape from the ordinary Vignoles rail. The two oblique pairs of wheels *M M* embrace the lateral and top parts of the rail-head, a little room being left on the top. The weight of the locomotive rests upon the four oblique axles, being carried on one side by a spring. The motor axle *B* is disposed horizontally, the motor being built into the locomotive frame. Each of the four axles is driven by a worm-gearing apparatus by means of the two endless screw-shafts *D D*, which are operated from the motor by a toothed gear.* The lateral broad supporting wheel *N* serves the purpose of backing up the locomotive and ensuring thereby equilibrium. This wheel is fixed on the side facing the canal, as the inclined tow-rope tends to tip the locomotive in this direction.



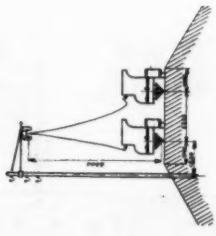
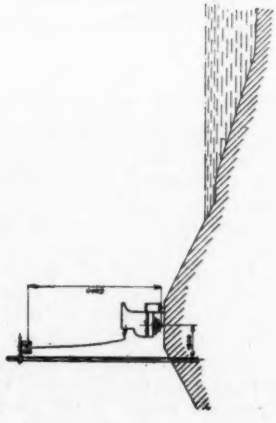
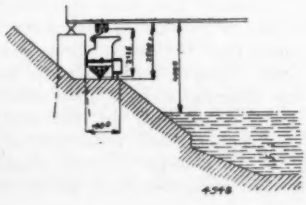


FIG. 3.



* The locomotive illustrated is built for three-phase current of 50 periods, it having been necessary, owing to the high number of revolutions and the low speed of the locomotive, to insert a pinion-gearing. At 15 periods this is not necessary, as the motor-shaft will serve direct for the driving of the worm-wheels, whereby the construction is considerably simplified.



Now, if the locomotive represented a rigid system the force of reaction on the rails causing the adhesion could only be as great as the weight of the locomotive itself, apart from that small part of the weight taken up by the wheel *N*. As the adhesion is to be increased by the wedging action of the weight, it has been necessary to provide for a certain mobility in those parts by which the weight of the locomotive is taken up and transmitted to the rails. For this purpose the locomotive weight can be shifted on the axles. The bearings of only two axles are rigidly built together with the motor, these two axles being on the same locomotive side. The axles on the other side are able to turn round the endless screw shaft *D* and the locomotive weight rests, on this side, by means of springs on the axle. In this way the relative position of the axles and the motor can be shifted in axial direction, and besides the axles of the one side can move round the shaft *D*. This mobility of the axles enables the weight to develop the wedging-action.

The extent to which the adhesional force is greater than the weight of the locomotive depends upon the incline of the wheel axles. The more they approach to the vertical, or in other words, the more the running-wheels deviate from the vertical, the greater will be the force of reaction. These forces arise direct in those places where the axles support the weight of the locomotive. If the wheel-axle forms with the vertical plane an angle *a*, the reactional forces amount to $\frac{Q}{\sin a}$, if we designate the weight of the locomotive with *Q*. If, therefore, the running-wheels incline to an angle of 45 degs. towards the horizontal, then the reactional-forces will be 41 per cent. higher than the weight of the locomotive. At an incline of 30 degs. they will be 100 per cent. higher.

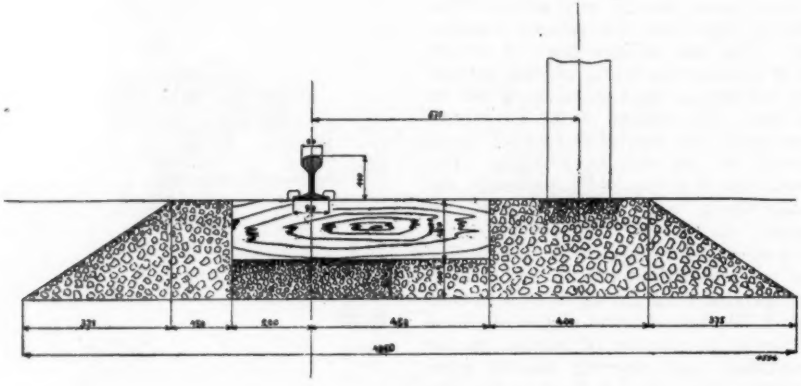


FIG. 4.

The reactional forces do not serve directly for adhesion forces, but have first to be transmitted to the running wheels, undergoing thereby a certain amount of diminution. This is understood, if we imagine that the movable axle can be turned round the screw-shaft, and is brought into its equilibrium by the weight of the locomotive, inasmuch as it rests upon the rail.

The arm of the adhesional force is a little longer than the arm of the reactional force, and, consequently, there is somewhat less adhesion utilised than reaction, this being determined by the wedging effect. Another small reduction of the adhesional force arises in such a manner that, at the adjustment of the movable

axle, the angle of friction asserts itself, inasmuch as one part of the weight is not balanced by the reactional force, but by the friction itself. In calculating, therefore, it is necessary to take into account an incline which is reduced by the angle of friction.

The importance of these factors is, however, not very great, owing to the fact that —(1) the lower bearing can be placed very close to the running wheel; and (2) the incline may be diminished at will. In the Teltow Canal scheme, for example, the conditions have been so arranged that the adhesion arising from the weight itself amounts to 186 per cent. of the weight.

However, this is only part of the adhesion. Another part will arise, as stated above, by the action of the pull developed by the tow-rope. This tow-rope is hung from the hook *C*, its direction forming an oblique angle with the locomotive axle, and, consequently, exercises a torque which tends to turn the locomotive round a vertical axle. The locomotive is balanced in such a manner that the two oblique pairs of wheels embrace the rail-head and are pressed against the same. The reactionary forces arising therefrom form a momentum whose arm is equal to the distance between the points of support of the two pairs of wheels. The torque exercised by the pull-rope will be the greater (1) the greater the tow-resistance to be overcome; (2) the greater the angle between the pull-rope and the locomotive axle; and (3) the greater the lateral distance of the tow-hook from the rail-axle.

From (1) may be deducted a very valuable quality in the locomotive, viz. the adhesional force adjusts itself automatically according to the amount of pulling resistance. The greater the resistance to be surmounted (such as wind, streaming water, bends, or steering), the greater will be the adhesion. This will be necessary, having regard to the greater tractive forces to be developed. On the other hand, with a lesser pulling resistance, the locomotive will be pressed against the rails only in so much as is required for the action of the tractive force, by which means no superfluous energy for the self-movement of the locomotive is lost.

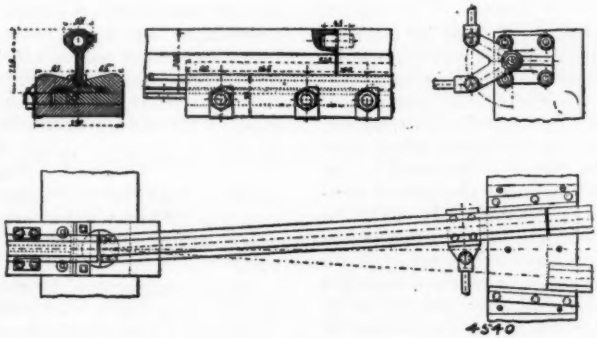


FIG. 5.

According as (2) the adhesion is diminished or increased, owing to the variations in the angle of pulling, so the driver of the locomotive (3) will be empowered to shift the seizing point of the towing-rope either in or out. The towing hook can either be shifted upon a screw-bar or fixed otherwise in five or six different positions at varying distances, this being tantamount to the regulation of the adhesion. It is, therefore, evident that this regulation can be carried out, not only according to the pulling angle, but on other occasions, such as, for

instance, on slippery rails when the pressure of the adhesion must be augmented.

In order to show what amount this adhesion represents in the total adhesion necessary, one case should be mentioned here, in which a towing-force of 1,500 kilogrammes was to be exercised. With the wheel-axles at a distance of 880 mm. the pulling momentum resulted in an adhesional pressure of 2,575 kg.; and as one-quarter of the same represents the towing-force which can be overcome by this adhesion, the former amounts to 644 kg. Consequently there remains 1,500 – 644 = 856 kg. of towing-force, for which the necessary adhesion has to be procured by the weight of the locomotive.

The momentum exercised by the tow-rope upon the locomotive serves not only for the increase of adhesion, but also assures the stability of the locomotive. The wheel-rims embrace the rail-head, and prevent the locomotive from tipping over. The more this danger is increased by the towing-forces, the more the power exercised by the wheel-rims. In fact, the solution of the question of adhesion by the use of light locomotives would be of no value if the danger of the locomotive being tipped over were not removed at the same time, for the lighter the locomotive the greater the chance of its being tipped over.

Now what is the difference between the weight of the ordinary tow-locomotive and the locomotive of the Ganz system? Let us take the case mentioned, since conditions vary greatly. An adhesion for a towing-force of 644 kg. was attained, so that 856 kg. remained for the weight. Since the adhesional pressure amounted to 186 per cent. of the weight, and 25 per cent. may be developed as towing-force, the weight of the locomotive therefore amounts to $856/1{\cdot}86 \times 0{\cdot}25 = 1{,}840$ kg. in order to be able to develop a towing-force of 1,500 kg. As, however, the conveyance of the locomotive itself requires a certain tractive force for the development of the same, the weight must be further increased by 136 kg. if a tractional resistance of 12 kg. per ton and a gradient of 20 per cent. is to be overcome. The outside bearing-wheel supports a weight of 300 kg., so that it is necessary that the total weight of the locomotive should amount to 2,276 kg. in order to have the power to develop a tractive force of 1,500 kg.

On comparing this weight with that of the Siemens system, the following result is arrived at, taking the same co-efficiency of adhesion as before. That part of the weight which has to supply the whole adhesion for the towing-force of 1,500 kg. rests upon one of the main rails. This part, therefore, amounts to 1,500/0,25 = 6,000 kg, which is equal to 85 per cent. of the total weight. The latter is consequently 6,000/0,85 = 7,060 kg. In order to overcome the tractive force of the self-conveyance on high grades of .20 per cent., the weight would have to be augmented by 1,035 kg. The locomotive must, therefore, weigh 8,095 kg. It appears, therefore, that the Siemens locomotive would have to be $\frac{8095}{2276} = 3.56$ times as heavy as the Ganz locomotive, and this difference in the weight naturally affects both the first cost and the working cost.

The arrangement of the locomotive may be seen from Fig. 1. It will be seen that the inclined wheels cannot score into the rail-head, owing to the fact that the direction taken by the reactional force is an inclined one. A small space is provided between the wheel-rims to prevent the wheels touching when the profile is worn. The brake *G* acts as a clamping-brake upon the rail-head, and not on the wheel-rims. This, however, is not of much service, owing partly to the low speed and partly because, the locomotive being built for three-phase current, the speed cannot increase on down grades.

In addition to the three-phase motor the equipment of the locomotive consists of a controller *F* (which can be actuated from behind as well as in front by a hand-wheel), a rheostat *J*, a switch *I*, and a plug-contact *K*, upon which is placed the trolley-contact with flexible cable. The driver's stand is placed laterally towards the canal, so that he can handle the instru-

ments and at the same time overlook the canal both in front and behind. The sheet-iron roofing of the locomotive is made round in front and at the back, in order to allow of the tow-rope of an approaching vessel to get over it with ease.

The rail is used as a third conductor to supply current at a tension of 500 volts to the overhead wires, which consist of two copper wires of 8 mm. diameter. A trolley car (Fig. 2) is provided for taking the current off the two overhead wires; this car runs along the wires on its two wheels. The design for taking off the current is characteristic, this being effected by a laterally disposed carbon-ring, which is pressed by means of a spring on to the by-piece of the wheel and slides on the same. The same arrangement in principle was applied by Messrs. Ganz & Co. to the roll-cylinders of the Valtellina Railway. The current is conducted to a contact shell by means of flexible cables. The contact shell is placed upon the plug of the locomotive. This cable also draws the trolley car, an arrangement which, taking into account the speed of 3 to 4 km., has nothing objectionable in it, especially as no switches are used in the overhead wires.

This trolley-car necessitates a distance of 300 mm. between the two contact wires. The suspension of the conductors (Fig. 3) has been designed to correspond. The two conductors are extended upon arms fastened to wooden poles at a height of about 3·5 m., placed along the tow-path at distances of 30 m. The two bells for the suspension of the wire, having Ambroin insulation, are each framed in a cast-iron socket, these sockets being screwed at both ends on a C-shaped bell-supporter made of gas-piping. This bell-supporter is fastened to the arm, which is also made of gas-piping, and which is fixed to the pole with a cast body. The wire-holders being made of tempered iron have an arm bent inwards, whereby the conductor interval is adjusted and fixed at 300 mm. The wire-holder is formed so as to allow of a safe and free passage to the trolley.

The wire-holders are remarkable. They are distinguished by the fact of their being very simply mounted, and also by the absence of any solder. It is, moreover, possible to loosen or tighten them from the ground with a special key. The wire-holder consists of two cheeks, which turn loosely round a joint-bar, on which bar is suspended a screw-bolt. A cone is screwed on the bolt, thus pressing the two cheeks aside, while the top part, being formed as a wireholder, clips the wire. The bottom of the cone is furnished with two wings, which fit into the opening of a special key for mounting. It is not necessary to secure the screws, as the cone cannot become loose of its own accord.

The contact wires are generally suspended at a height of 6 m. In being carried under bridges the wires are suspended by the same C-pieces, with the difference that in this case they are screwed to the floor of the bridge by means of hoops. The flexible cable admits of the passage underneath the lower bridges without any difficulty. In bends, as well as in the rail switches, the arms are prolonged, their length amounting on the level to 500 mm. and at bends to 1,500 mm.

As already mentioned, no aërial switches are used in the contact wires, so that there are no branchings in them. In the rail switches the two conductors are led between the two rail lines in the middle, as shown by Fig. 3. As the greatest distance between the tracks in these places amounts to 2,200 mm., the flexible cables of the trolley-cars permit of the use of common contact wires. When two locomotives meet on the track they only have to change their trolley-cables, which is tantamount to putting in or withdrawing a plug contact. The trolleys themselves describe a pendulum circuit, and the locomotives pass through.

The rails are placed on wooden sleepers at a distance of 800 mm., and to these the rail is fastened with three nails, of which, having regard to the oblique pull of the rope, one is driven in at the side towards the canal and two on the opposite side. For the same reason the rail is not fixed to the middle of the sleeper, but in such a manner (Fig. 4) that two-thirds of the length of the sleeper

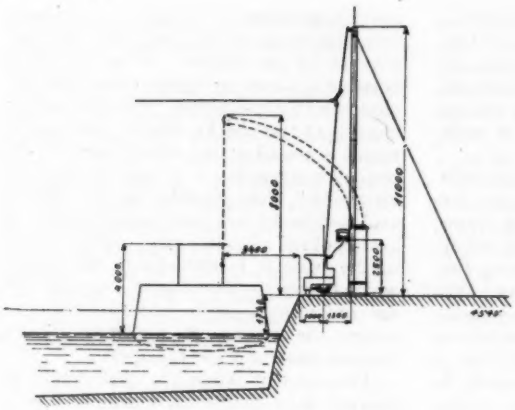


FIG. 6.

come upon the canal side and one-third on the opposite side.

The rail-bondings are so formed as not to interfere with the passage of the wheels. They consist of two steel shoes, which embrace the rail-foot on both sides. The upper shoe has, below the rail-foot, four cuttings for the head-bolts which, being put through the other shoe, are tightened by means of a nut. Taking into consideration the comparatively low force with which the tow-rope endeavours to remove the two rails, this bonding is a safe one, and cannot, at the low speed and inconsiderable pushes of the light locomotive, get loose, especially as the locomotive is not followed by cars which repeat these pushes. A copper connection between the two rails provides for the conducting of the electric current.

The arrangement of the switches at the meeting-places of the locomotives and at the loading and unloading places may be seen from Fig. 5. The switch-tongue is adjusted and fixed in position by a lever-arm. This work is done by the locomotive driver himself, although it can be arranged automatically. For the passage of the supporting-wheel over the other rail of the siding, counter-rails are fixed in the respective places.

The arrangement which Messrs. Ganz & Co. have contrived for carrying the tow

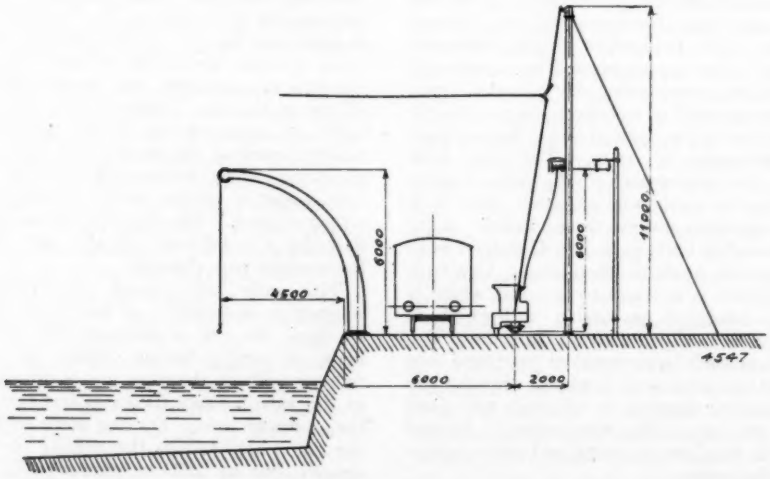


FIG. 7.

rope over the loading and unloading places is entirely new. In these places the tow-rope must be carried without hindrance over the stationary barges, and must, therefore, be at least 4 m. above the water-level. Moreover, it is necessary that the loading and unloading cranes should be able to work without interruption, the arrangement having to be such as to render the use of the shore-street and the erection of a barrow-bridge as easy as possible.

The chief factor in carrying out this task is in the use of a small auxiliary carriage, which conducts the tow-rope at a suitable height. This carriage is run on trolley-like wheels along steel ropes extended close to the shore. The rope is conducted from the locomotive to the auxiliary carriage, and thence in an almost horizontal direction — say, at a height of from 10 m. to 12 m.—to the top of the poles on the vessel, it being therefore too high to allow of any obstacle interfering with its service.

There are two alternatives for carrying the ropes, these being represented in Figs. 6 and 7. In the first the locomotive runs close to the shore, in which case the cranes should be erected somewhat further back, at the height of the bars carrying the steel wire. By this means fixed rotary cranes are especially kept in view, but there is no objection to the use of portable cranes with arms. As will be seen from the drawing, the towing arrangements will only interfere with the cranes in so far as when, at the passing of the locomotive, they are turned to the canal side, it will be found necessary to turn them back 90 degs. At the moment the crane is being turned the load must be lifted which eventually might have hung on the crane, provided this load has already been lowered about 2·5 m. above the shore-level. At this height the electric contact wires at the loading and unloading stations are extended. It is necessary to turn the crane in order to allow the tow-rope to pass by. The height of the cranes at this alternative has been determined in such a manner that the crane arm, together with the load, might during the turning of the load be led over the electric conductors. The conductors are protected against accidental touching by a three-sided wooden partition, lest short-circuit might be effected by the crane chains.

Another alternative is given in Fig. 7. On this the track is not laid quite close to the shore, but is shifted a few meters further out. On the other hand, the cranes are placed exactly on the shore border, their working not being interfered with by the towing service. The cranes need not be so high, there being no danger of contact with the conductors when the cranes are turned. The electric conductors need not be carried so low, and may be left without any external protection.

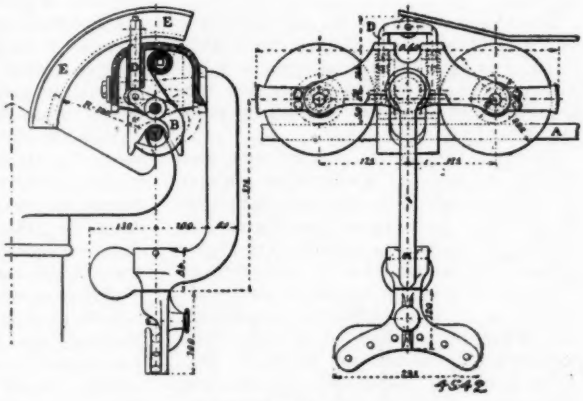


FIG. 8

At the loading and unloading places the tow-rope is considerably longer, as it is conducted at a very oblique angle to the guiding carriage. Consequently, the vertical component of the pull does not exercise any considerable action on the locomotive.

The guiding carriage is shown in Fig. 8. The arm which connects the two broad-rimmed running-wheels has an arm projecting downwards. The latter carries the rope-guiding bow, which can be freely turned round a pivot. The tow-rope is put into the bow from the side. Rollers are imbedded in the bow, upon which the rope is carried towards the locomotive or barge. It should be remarked, however, that as soon as the tow barge approaches the loading and unloading stations, the tow-rope is suspended with a second ring on the hook of the tow-pole, the length of the rope between the locomotive and the barge being thereby considerably increased.

In order to minimise the self-resistance of the running-wheels, they are fitted with roller bearings. The guiding-rope is so fastened to the poles as to enable the guiding-car to pass over these points without difficulty.

Owing to the pull of the tow-rope, the guiding-car assumes a somewhat oblique position, though this does not endanger its stability. A counter-weight is provided in order to ensure the stability of the locomotive, and, in addition, a safety-device. The latter consists of a hook, *B*, surrounding the rope; in the event of the guiding-car being tipped over, it is then held suspended by the hook on the rope. The hook is made in the shape of a two-arm lever, and is generally held in position by a spiral spring. At the points of support a guiding-path, *E*, is provided, and this presses down the hoop, *D*, and turns up the safety-hook in such a manner as to enable the guiding-car to pass over the supporting points.

The steel rope is fixed to steel poles at a height of 11 m.; at the terminal points of the loading and unloading places, however, they are lowered to a height of 2 m., and fastened to low-anchored poles. The guiding-cars are stationed on the rope at these points, and these consequently never leave the loading stations. There are two guiding-cars at all points of entrance. When the locomotive enters the loading place, it passes near the terminal pole, while the tow-rope is taken off the hook and put in the guiding-car, the rope with the lower ring having been previously put into the pole-hook by the steersman. The locomotive runs further, so that the tow-rope first slides on the roll through the bow, and the car is then pulled up on the guiding-rope. The same procedure is repeated in opposite order when leaving loading places, the locomotive standing still until the tow-rope has slackened enough to enable it to be placed in the pole-hook on the first ring.

The foregoing are the general technical outlines of Ganz's canal-haulage system. In order to give some idea with regard to the financial side of the system, *i.e.* the first cost as well as the cost of carrying it on, we append below some comparative data showing the first cost and working cost of other systems. The results of the Teltow Canal competition will best answer this purpose, since the figures given refer to the conditions exactly as they were prescribed and to which the schemes were adapted. They consequently allow of a direct comparison being made between the cost of investment and the cost of working of the various systems. The following figures refer to a canal of about 37 km. in length, with an annual goods traffic of 1,500,000 tons. The schemes which were given awards and on which the working costs have been based on an individual price of 12 pfennigs per kilowatt-hour show the following figures:—

	First Cost. Marks.	Working Cost per ton kilometer. Pfennige.
Siemens & Halske ...	2,500,000 ...	1·07
Feldmann & Zehme ...	? ...	0·667
Kanaltauerei Ges. System Rudolf ...	2,597,000 ...	0·61
Ganz & Co.	1,007,980 ...	0·43

According to these figures, the first cost and working cost of the Ganz system are more favourable than the other systems. This is accounted for by the light locomotive, the suitable permanent way, and simple equipment of the loading and unloading stations.

High-Speed Engines.

The Influence of Governing on Torque.

By J. H. DALES, A.M.Inst.C.E.

(Continued from page 107.)

❀ ❀ ❀

Methods of Avoiding Knock.

Ever since the first introduction of high-speed engines for modern purposes, in which usually quiet running is desirable, efforts have been made from time to time to devise means for preventing knock of those bearings which are subject to the reciprocating actions of an engine, notably those of the piston and valve lines. Having shown some of the chief causes of the more troublesome kinds of knock, it may be useful at this stage to deal with such devices as have or partly have overcome the difficulties which lead to knock. The general process of invention in this line has been one of costly evolution, much of which might have been avoided by more careful preliminary investigation in the early stages. This applies to most things, but in particular the developments hereafter dealt with are an object-lesson in the value of applied science as an economic factor. Imperfect data often render experiment necessary, and, moreover, much valuable information and experience is constantly being lost for want of better methods of record; and, as a consequence, the same ground has often to be worked over again and again by different people, because they are ignorant of what has been done before. In one of the following cases there were no fewer than five costly patents and sets of experiments carried out in this country at an expense of many thousands of pounds, besides others in America, within a period of seven years.

At first it was thought that some automatic method of taking up the wear of bearings which were subject to knock might meet the case. For this purpose appliances were made to keep the brasses quite close up, while others were designed to always leave a minimum clearance.

The actual difficulty however proved to be that whilst a $\frac{1}{800}$th of an inch clearance gives a very audible knock at over 300 revolutions per minute, the expansion of a hot bearing of, say, a 4-inch journal and $1\frac{1}{4}$ inch total of brass, between 60 degs. and 400 degs., amounts to about $\frac{1}{60}$th of an inch; and, consequently, any adjustment which is close enough to avoid objectionable knock inevitably leads to seizing of the surface if the lubrication fails or other cause leads to heating of a bearing. So these contradictory necessities of a suitable provision led to the abandonment by most designers of the fixed adjustment systems, and single-action engines occupied their attention. These, however, were so

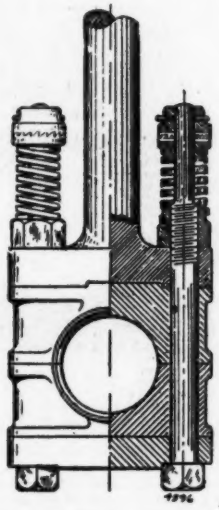


FIG. 1.—ABERCROMBIE'S SYSTEM OF SPRING-COIL AND NUT BEARINGS.

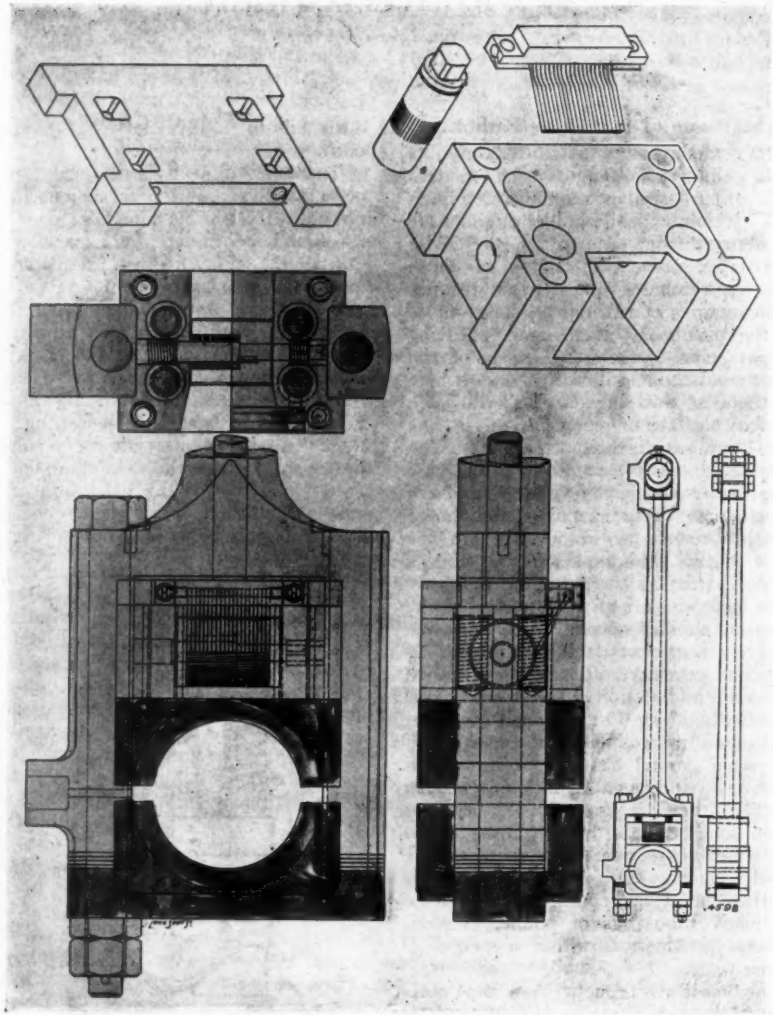


FIG. 2.—DALE'S METHOD OF UTILISING A MOTION OF THE BRASS.

dependent upon compression for keeping the bearings in contact during the in-stroke, and at excessive speeds also in the early part of the out-stroke, that Mr. Willans introduced the permanent air-compression cylinder, which is one of the chief features, perhaps, in a mechanical sense of his engine. The advocates of double-acting engines, however, have endeavoured to retain the advantages attached to this class, by working two single-acting pistons together in one cylinder, so that the out-stroke should be performed by the back piston and the in-stroke by the front piston, the back piston-rod usually passing through the tubular one of the front piston, each being in connection with its respective brass or bearing. This system has been patented by several inventors both in England and America. Apparently the first in the field was Ferranti, Pat. 4505/85.

Other double-acting engine designers allowed a clearance which would be ordinarily sufficient to be out of the reach of expansion in their fixed bearings, and sought to avoid knock in some degree by flooding the bearings with oil to form a cushion. In this direction Belliss introduced forced lubrication, usually under a pressure of 15 lbs. to 30 lbs. per square inch. The former seems to be sufficient.

For the double purpose of maintaining a quite close-up adjustment of brasses and bearings, and at the same time allowing for any expansions of these due to heat of running, the writer brought out his hydraulic system (Pat. 9,697/94), which consists of a spring ram (properly packed for liquid pressure), which, on the non-working stroke, places the brass on which it bears, in close contact with its journal. The ram cylinder is in communication with a reservoir of liquid, with a back-pressure valve against the ram cylinder. The action of placing the brass close up, and consequent movement of the ram, draws liquid through the back pressure and also into the ram cylinder; but when the shock of the working strokes comes on to the liquid it instantly closes the back-pressure valve without any appreciable escape of the former, and holds the brass to its work, with no more elasticity of fixture than that of the liquid, which is very slight. This system has been quite successful in accomplishing the object aimed at, and engines which have been fitted with it have made extraordinary speeds and length of runs. Six-inch strokes have easily accomplished 600 revolutions per minute regular running, with ordinary drop-feed lubrication and very ordinary attention; while large engines have run with continuous lubrication for long periods, on day and night work, without stopping.*

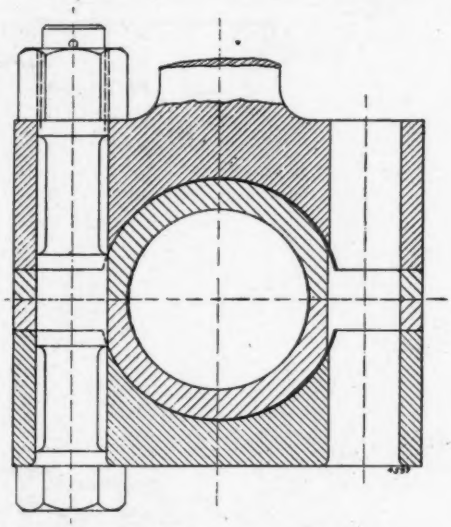


FIG. 3.—EXPANDING BRASSES: MARINE ALL-BRASS BIG AND SMALL ENDS.

Fig. 1 shows Abercrombie's system of spring coil and nut for taking up wear through any fixed range. The spring coil is fixed at one end by collar and ratchet collar to the bolt end, while the other end actuates the nut by screwing it up as wear takes place. Any necessary tension can be put upon the coil for performing its

* Attempts have been made experimentally to make this system seize on the bearings by running engines dry at 450 revolutions, with a jet of water playing on the bearings. The process was not good for the surfaces, but the engines could not be stopped by seizing.

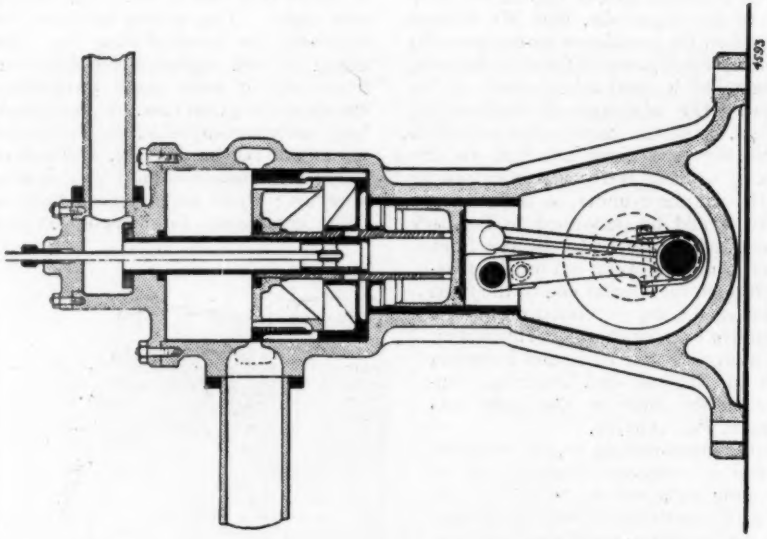


FIG. 5.—FERRANTI'S DOUBLE SINGLE-ACTING PISTONS.

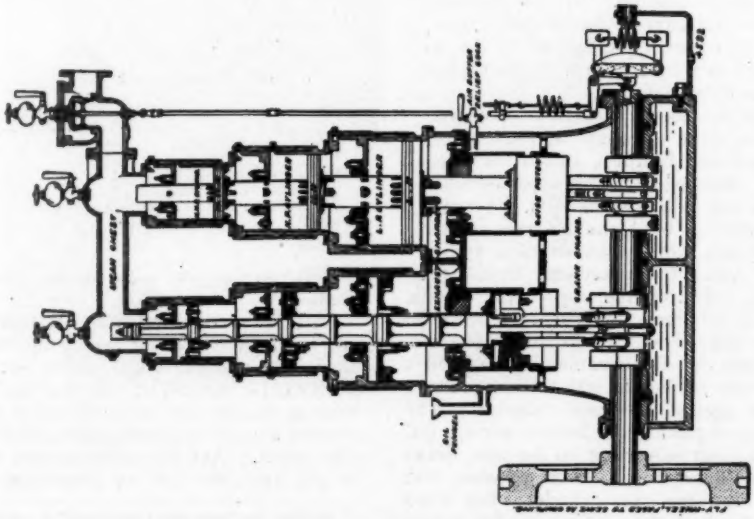


FIG. 4.—WILLANS' AIR-COMPRESSION SYSTEM.

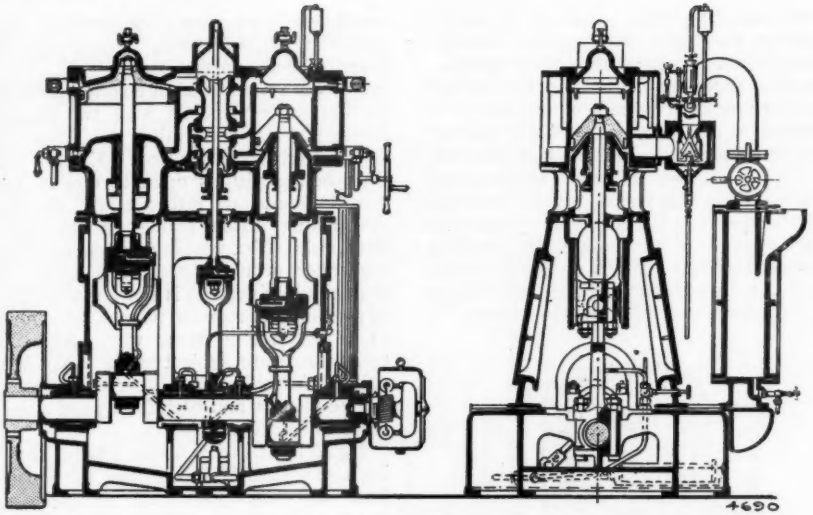


FIG. 6.—BELLISS SYSTEM OF FORCED LUBRICATION.

functions, by means of the ratchet collar, which is provided with tommy or key holes.

Fig. 2 shows a method of utilizing a motion of the brass through the distance of an allowed clearance for purposes of automatic adjustment. A spring or set of springs are placed so as to always keep the loose brass of a bearing against the journal. A reciprocating action of the brasses or journal thus produces a motion of the brass in question through a given clearance or distance. This motion is transmitted to a ratchet wheel by means of a differential pawl of such a degree of fineness that it will, by means of the ratchet, screw up a stop to the loose brass, as far as the allowed clearance, in case, by reason of wear, such clearance should be exceeded. The actual clearance for lubrication takes place between the journal and the fixed brass. In the example shown, which is of an application to a connecting rod, a sliding block contains all the adjusting arrangements, and transmits the adjustment also to the small end of the connecting rod by means of a rod passing down a hole in the centre of the former. The pawl is formed of twenty spring leaves, all of the same length, while the ratchet wheel is cut atwist to the extent of one pitch in its length or face. The tooth pitch being 20 per inch, it follows (slack fits not taken into account) that a clearance movement, as aforesaid, of a little over $\frac{1}{400}$ of an inch would produce the adjusting motion.

Fig. 3 shows an arrangement of brass and bearing in which the expansion of the brass would keep pace or distance with the expansion of the journal, if the proper proportions of diameter and length are provided. The brass is supported by lugs, so as to leave the brass free to expand in diameter of eye. The expansion of the brass up to an amount equal to the distance of the radius of the journal would be outwards (to increase the diameter of the eye), and if this is more than equal to the expansion of the radius of the journal, the object of maintaining the clearance would be accomplished through any range of temperature.

The expansion of brass to steel is about 10·4 to 6·1, so the brass would always have a lead on the journal. The expansion of the lugs would stretch the bolts, which should be as long as possible, so as not to get beyond the limit of elasticity. The brasses, needless to say, should be

well bedded together, otherwise the expansion of the lugs inwards would deduct from the desired result. This arrangement is useful in connection with forced lubrication, as it admits of the use of a minimum clearance. All-brass marine connecting-rod ends embody this principle.

Fig. 4 shows Willans' single-acting engine with guide piston, which is utilised for compressing the air in its cylinder for the purpose of preventing the working brasses leaving the crank on the in-stroke, and also for assisting the early part of the out-stroke when the steam pressure is insufficient to overcome the inertia of the piston-line to the speed. The figure in other respects explains itself.

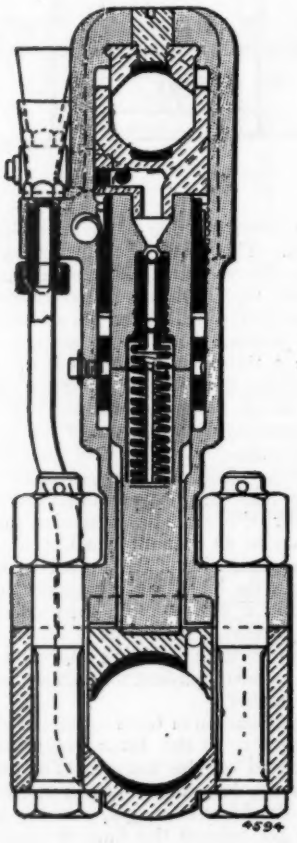


FIG. 7.—DALES' SYSTEM OF HYDRAULIC ADJUSTMENTS.

Fig. 5 is a portion of an engine provided on Ferranti's principle with two single-acting pistons, performing the functions of one double-acting piston. Each of the single-acting pistons operates one of the connecting-rod or rather crank brasses, the pulling piston acting on the outer brass, while the pushing piston operates the inner or near brass or bearing. A difficulty in this type is the accumulation of pressure between the pistons, which has to be set free in some way. Also the two pistons are subject to the same difficulties of inertia as are other single-acting engine pistons, and each for a good action requires similar provisions.

Fig. 6 is part of a Belliss engine showing the system of lubrication, the dotted lines and tubes indicating the passages for the oil pressure. The oil reservoir is in the engine bed-plate, and the pressure pump driven off the eccentric. The oil is led to the centre of the different bearings as nearly as possible.

Figs. 7 and 8 are an engine connecting rod and main bearing fitted with the writer's hydraulic adjustments, which at the same time take up all wear and allow for expansion due to heat. Referring to the main bearing (Fig. 8) as the simpler embodiment, it is seen that the top brass is held down in position by a ram, in the centre of which a spring is placed, the latter bearing on the ram cylinder cover or gland. A screw plug in the top of the ram cylinder is provided for adjusting the clearance of the ram in the cylinder. The plug really forms the cylinder end. On the top of the ram an oil or liquid reservoir is formed by a continuation of the gland or cylinder, the same part serving for both. In the body of the plug a passage is formed from the oil reservoir to the ram cylinder, and in the passage is a back pressure valve formed of a ball. The action is obvious. When the working pressure is on the bottom or fixed brass the top brass is free and is pressed close on the journal by the ram and spring, oil passing freely through the ball valve to fill any vacant space which

may occur in the ram cylinder by reason of the action of the ram. Of course, the quantity passing is extremely small. When the up-stroke of the engine takes effect upon the top brass the shock is imparted to the liquid, which instantly closes the back-pressure valve by the hydraulic pressure so created, only a very small quantity of liquid escaping to the reservoir. The same action is repeated every up-stroke and down-stroke. The lift of the ball-valve is about $\frac{1}{100}$th of an inch, and the extreme rapidity with which it will perform its functions leaves nothing to be desired; 600 revolutions per minute makes no approach to its limitations. If the plug which forms the ram cylinder end is so adjusted as to leave more clearance than can be taken up by the expansion of the journal and two brasses, the bearing can never become "solid," and therefore could not stop the engine by seizing. This is an important point, as in many cases and situations it is necessary to keep an engine running whatever the condition of the bearings may be.

The connecting rod (Fig. 7) is shown with a double ram, with a spring between the inner ends (really in a hole in each). The spring on the pulling stroke of the engine pushes both large and small end brasses on to their respective necks. A spring-loaded reservoir is provided to make good the leakages through the packings, and a ball back-pressure valve is, as before, placed in the passage to the ram cylinder. The action is similar to that already described. Sufficient clearance is allowed between the ram ends to prevent the accidental expansion of both sets of brasses from bringing the ram ends together.

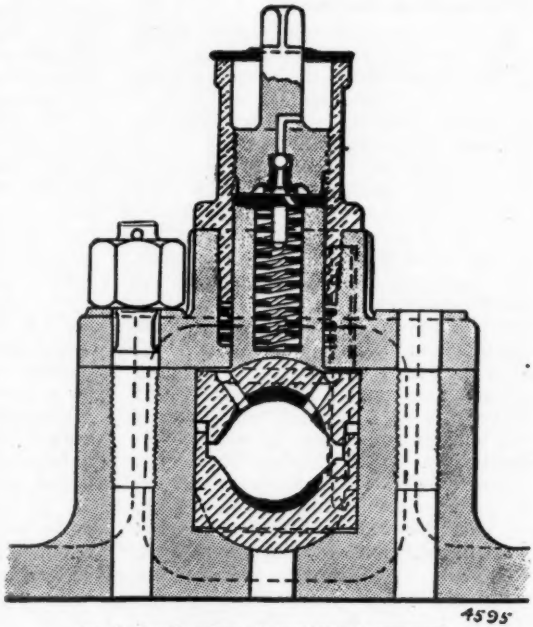


FIG. 8.—DALE'S SYSTEM OF HYDRAULIC ADJUSTMENTS.

Although all the standard methods accomplish their object more or less, good design in the matter of the principal forces while at work still further increases the quality of the results. The less there is to do, the more easily is it accomplished.

(To be continued)

The Paris Metropolitan Railway.

By JACQUES BOYER.

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1. History of Metropolitan Railways.

AMONG the chief capitals of the world, Paris, only a short time ago, held the record for the congested state of its streets and the slowness of its public conveyances. Now, however, mechanical traction along the main thoroughfares of the Ville Lumière, is being rapidly developed: and, a few years hence, electric trains may be expected to circulate in all directions under the ground upon which the ancient French city is reared, and which has so often been disturbed and dug up already. It is none the less true, however, that the Paris Metropolitan Railway was not opened until the year 1900, whereas, in London, the first Metropolitan line was completed thirty years since. In fact, the section of the underground railway extending from Paddington to Farringdon Street was declared open for traffic as long ago as January 10th, 1863. In New York, an overhead Metropolitan Railway has been in operation ever since April 25th, 1878, the metal girders whereon the rails are laid being supported by iron pillars erected along the side-walks. Since 1882, Berlin also has possessed 11 kilometres (about eight miles) of overhead railway lines, traversing the German capital from east to west, viz. from the Frankfort Railway Station to the Charlottenburg Station, not to mention 37 kilometres (about 25 miles) of railway, forming an "outer circle," run for the benefit of suburban residents, while it also serves to establish communication between the termini of the main lines connecting the capital with the provinces. To close this list of foreign Metropolitan Railways, those of Vienna, Chicago, and Philadelphia, all of which have been in existence for more or less considerable periods, may be mentioned.

The idea of a railway across Paris has engaged the attention of several successive generations of engineers, but the originators of the first sound scheme were Eugène Flachat and Brame, who suggested the construction of an underground line for the conveyance of supplies of provisions to the great Paris market, the Halles Centrales (1853). Then came, successively, the somewhat vague plans of Le Hir, Le Masson, Vauthier, Letellier and Guerbigny, which may be passed over in silence. Next, in 1872, a Commission, appointed by the Prefect of the Seine Department, considered the question more closely. M. Mantion, reporter to the committee, in a very able manner stated the conditions under which the problem was to be solved; and, indeed, for a period of two years (1875-77), the Municipal Department of Public Works caused certain preliminary investigations to be made. Yet, for over eighteen years, it had proved impracticable to carry out the project prepared by the Commission. owing to differences of opinion between the municipal authorities and the State. The members of the Municipal Council considered that the Metropolitan Railway should be reserved for the sole use and benefit of the town residents, while the Government proposed to use it for the purpose of connecting the termini of the several large railway companies, viz. the Western, the Northern, the Eastern, the Orleans, and the Paris, Lyons and Mediterranean Railways. Fortunately, the approaching Universal Exhibition put a stop to the barren discussion; and in 1895 the Minister of Public Works acknowledged the right which the Municipal Council claimed, to carry out the railway system in question as a matter of local interest merely. Eventually, after a series of investigations, counter-investigations, and other red-tape formalities, which are so lengthy in France, a law was enacted on March 30th, 1898, recognising

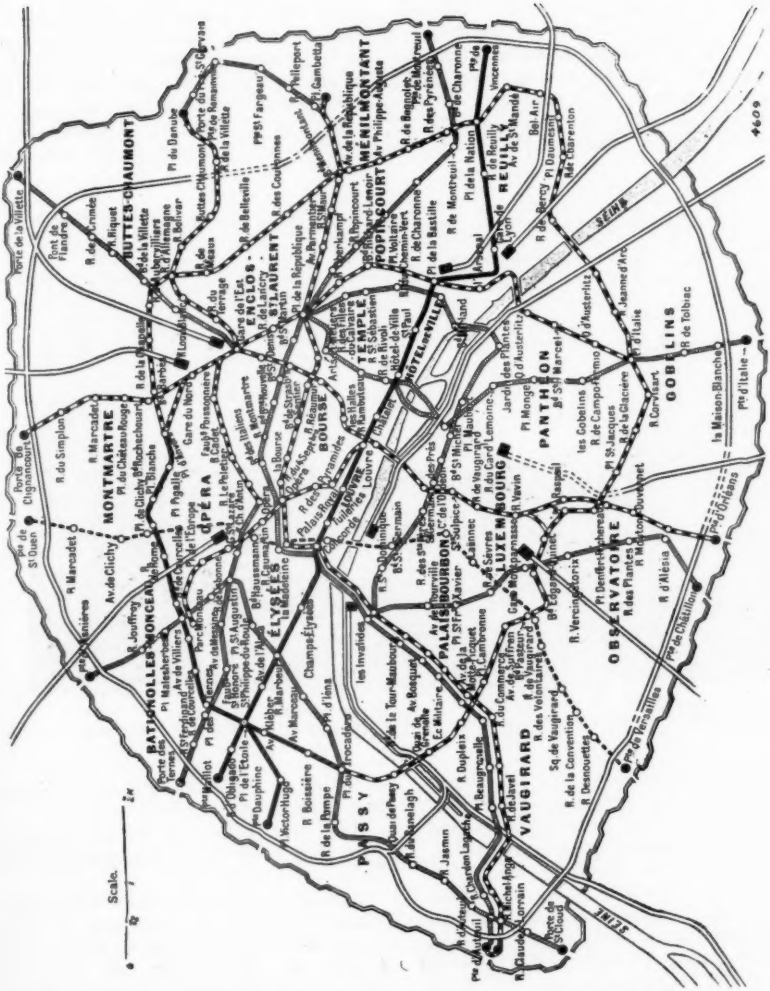


FIG. 1.—PLAN OF EXISTING AND PROJECTED METROPOLITAN LINES IN PARIS.

the status of a Paris Metropolitan Railway as a scheme of "public utility."

General Observations on the Plan adopted for Paris.

Under the scheme sanctioned by the French Parliament the Paris Town Council undertook to build the substructure, such as the underground foundations, viaducts, trenches, and excavations; the contractor (who is to "run" the line) undertaking to carry out the superstructure works. As a result of the submission of competitive tenders, the Municipal Council granted the contract to the Compagnie Générale de Traction, connected with Schneider's well-known Creusot works. This, then, led to the formation of the Compagnie du Chemin de fer Métropolitain in 1899. The contract was conceded for thirty-five years, at the expiration of which period the several lines should revert to the Municipal Council (*la Ville*) successively in the order in which they were opened for traffic. Furthermore, the Council reserved for themselves the option of repurchase of the lines seven years after the last section had been declared open. The contractors take the receipts, after deducting a royalty payable to the Municipal Treasury at the rate of 10 centimes per first-class passenger (full fare 25 centimes) and 5 centimes per second-class passenger (full fare 15 centimes). In the event of the number of passengers exceeding one hundred and forty millions per annum the royalty shall progressively increase up to fr. ·105 and fr. ·055 respectively, in proportion as the number of passengers conveyed shall get nearer to the maximum of one hundred and ninety millions.

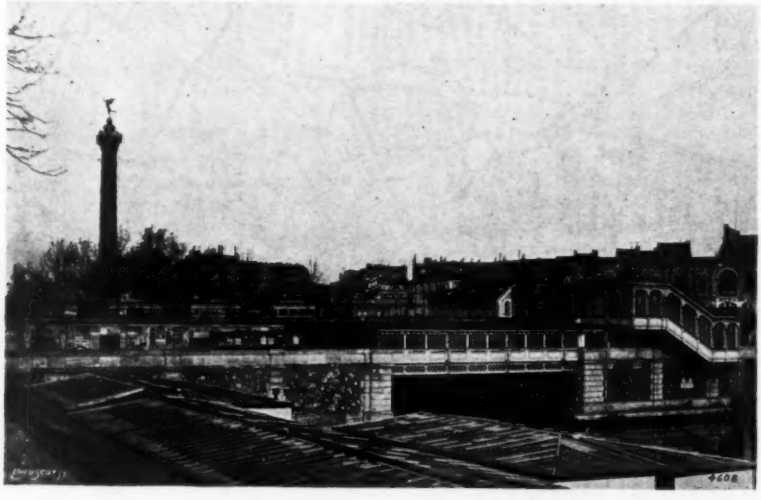


FIG. 2.—PASSAGE OF THE METROPOLITAN RAILWAY OVER THE ST. MARTIN CANAL NEAR THE PLACE DE LA BASTILLE.

The construction of the following six lines (Fig. 1) was in the first place decided on:—

Line A. To traverse Paris from east to west—viz. Porte de Vincennes to Porte Dauphine. Length of line, 11 kilos. 17 ms.

Line B. A circular line along the old outer boulevards. Length of line, 23 kilos. 763 ms.

Line C. From Porte Maillot to Ménilmontant. Length of line, 8 kilos. 645 ms.

Line D. From Porte de Clignancourt

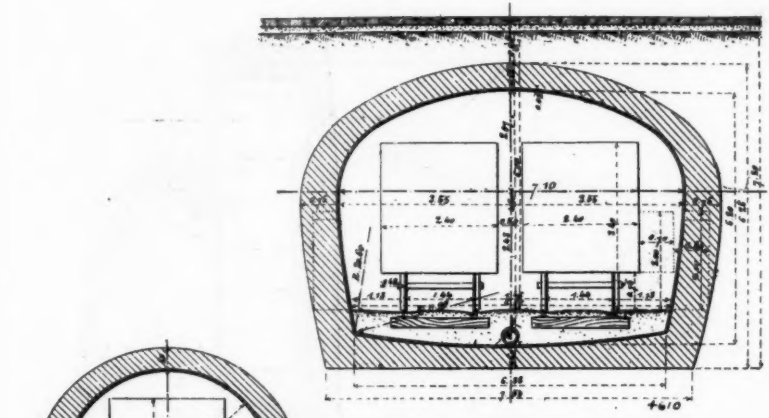


FIG. 3.—SECTION OF ARCH: DOUBLE LINE.

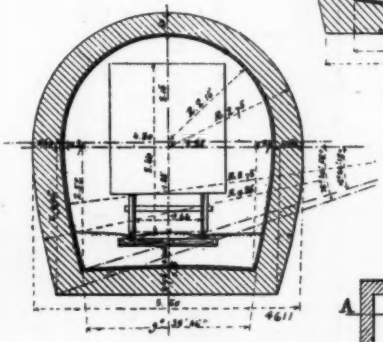


FIG. 4.—SECTION OF ARCH: SINGLE LINE.

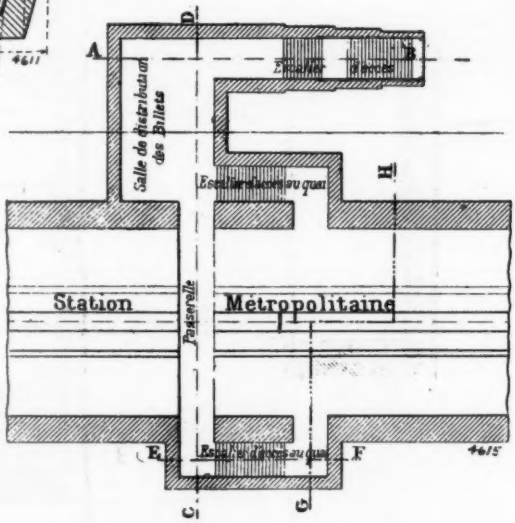


FIG. 5.—TYPE OF STATION: PLAN.

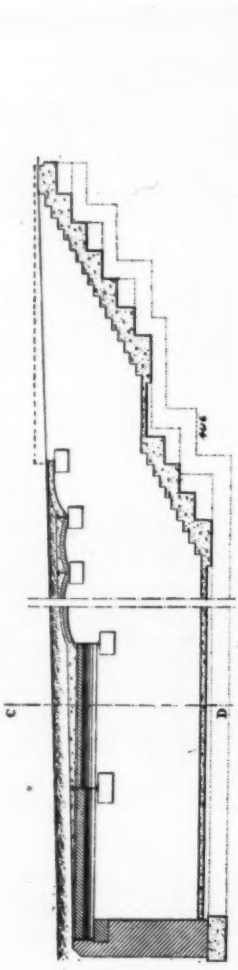


FIG. 6.—TYPE OF STATION: APPROACH FROM ROADWAY.

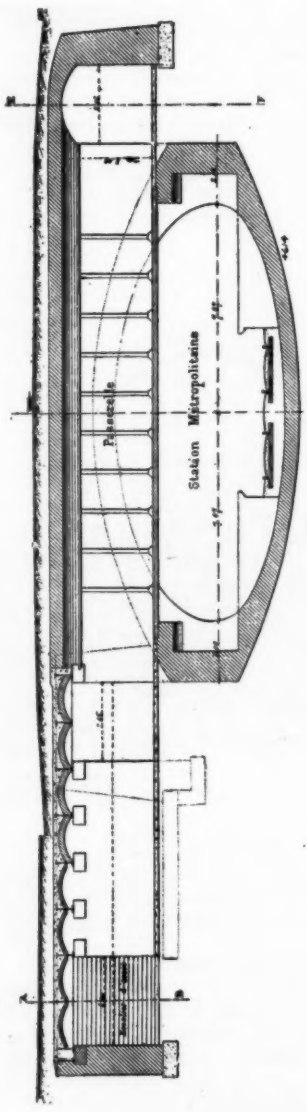


FIG. 7.—TYPE OF STATION: TRANSVERSE SECTION.

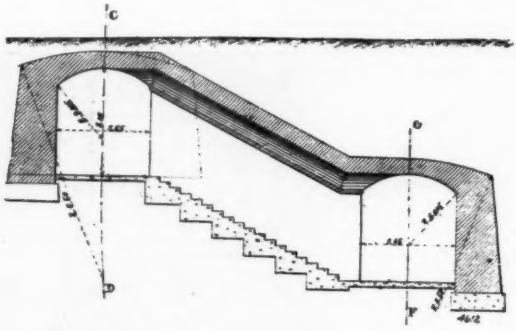


FIG. 8.—TYPE OF STATION: APPROACH STAIRCASE.

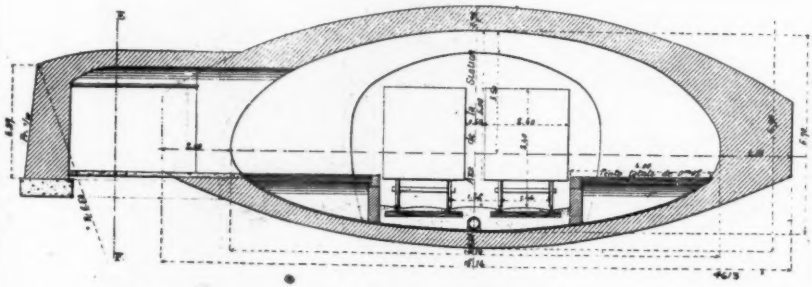


FIG. 9.—TYPE OF STATION: ANOTHER SECTION.

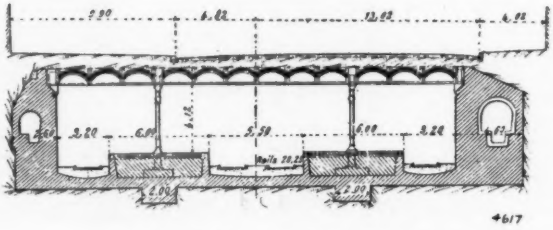


FIG. 10.—THE LYONS TERMINUS: SECTION.

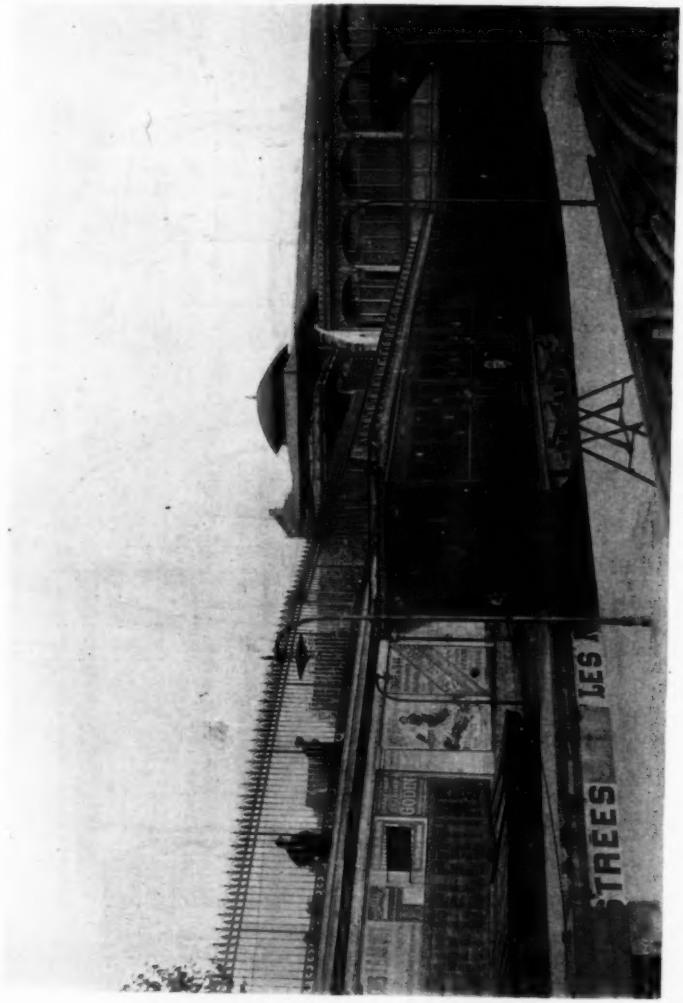


FIG. 11.—VIEW OF THE BASTILLE STATION: INTERIOR VIEW.

to Porte d'Orléans. Length of line, 11 kilos. 427 ms.

Line E. Joining the Boulevard de Strasbourg to the Austerlitz Bridge. Length of line, 4 kilos. 915 ms.

Line F. Connecting the Cours de Vincennes with the Place d'Italie. Length of line, 5 kilos. 929 ms.

It is, moreover, contemplated, in the near future, to complete two additional lines, one from the Palais Royal to the Place du Danube (6 kilos. 500 ms.), and the other from Auteuil to the Opéra, viâ Grenelle (about 7 kilos.), not to mention M. Berlier's project, which suggests connecting Montmartre to the Versailles Gate. This last section is to be at a depth of 40 metres underground, so that there shall be no necessity to interfere in any way with the foundations of the houses. For crossing the Seine, it is intended to construct two cast-iron tubes, cased in a thick layer of cement, and to lay them 10 metres below the bed of the river.

The 78 kilometres of the Metropolitan system, for which grants have, so far, been obtained or applied for, will cost, in round figures, frs. 300,000,000. Towards this amount, the Municipal Council will contribute from frs. 230,000,000 to frs. 240,000,000, while the company who shall secure the contract are to provide from frs. 60,000,000 to frs. 70,000,000 for the superstructure, which will raise the cost per kilometre to frs. 3,800,000, when complete for traffic.

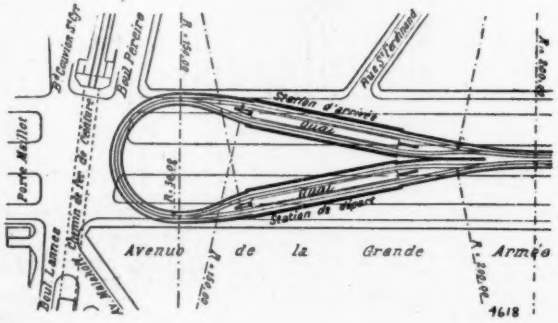


FIG. 12.—PLAN OF THE TERMINUS, PORTE MAILLOT.

Description of A and B Lines. Methods of Construction Adopted.

Before proceeding with the construction of the underground track for line A (Porte de Vincennes to Porte Dauphine), certain preparatory works had to be carried out. To begin with, four galleries connecting the line of the proposed railway with the Seine were cut for the purpose of removing the detritus and conveying building materials to the yards. The length of these galleries, which are still, provisionally, kept open, varies between 212 and 436 metres. The next thing which required attention was the completion of a new sewer, in substitution for that which had run along the axial line of the Rue de Rivoli, while the water-pipes supplying part of Paris had also to undergo certain substantial alterations. All this involved an expenditure of upwards of frs. 5,000,000. When this preparatory stage had been gone through, the construction of the first section of the Metropolitan Railway System was commenced. The work was divided into eleven sections to be carried out partly by sub-contractors and partly by the Municipal Administration themselves (under the special powers given them for the purpose), under the supervision of M. Bienvenue, Chief Engineer, assisted by M. Biette. The amount

of earth to be excavated and removed was not less than 310,000 cubic metres. The weight of the metal employed (viz. cast-iron and steel) reached the figure of 3,600 tons. These figures, of course, apply to the substructure works only.

Line A, including its two branches leading from the Étoile to the Porte Maillot, and to the Place du Trocadéro, respectively, is wholly underground, with the exception of the passage of the St. and Trocadéro lines, somewhat steep gradients had to be resorted to, there being at this point a difference of 16 metres between the level of the road and that of the ground.

Along the whole of the normal course of the line the railway is a double-line one, save as regards the loops of the termini and the junctions between one line and another, where single-line galleries were adopted.

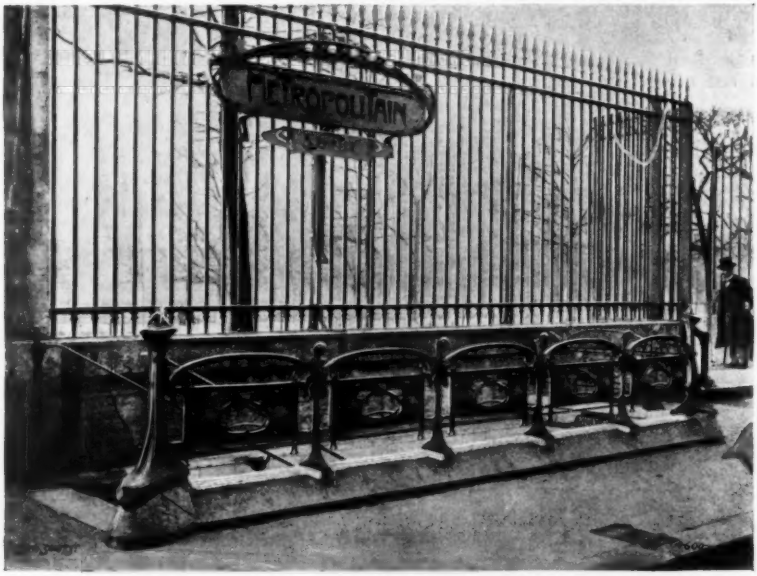


FIG. 13.—ENTRANCE TO THE TUILERIES STATION.

Martin Canal, which is carried out in the form of an open viaduct or bridge, as shown in the accompanying photograph (Fig. 2). Generally speaking, the tunnel is but a little distance below the street pavement, though at the Boulevard Sébastopol and Place de la Concorde, where it was necessary to cross the main sewers, the masonry had to be lowered to a greater depth. Similarly, in the vicinity of the Place de l'Étoile, where the Étoile and Porte Dauphine branch passes under the Vincennes and Porte Maillot and the Étoile

Elliptic arches of 7·10 metres span, 2·07 metres rise, and 55 centimetres thickness at the crown, constitute the ordinary type of arch along the underground double line (Fig. 3). The abutments, or side walls, 75 centimetres thick, are connected at the base by a floor in the shape of an inverted arch, which supports the permanent way. Besides, on either side of the tunnel niches are arranged, lozenge-fashion, at a distance of 25 metres apart. This section of line had to be slightly enlarged at curves of less than 100 metres, the interior

of the work being lined with a continuous coat of cement plaster, 2 cm. thick.

The single-line subway (Fig. 4) has a horseshoe section, the semi-circular arch of 2·15 metres radius and 50 centimetres thickness at the crown, the side walls being 4·30 metres apart, 60 centimetres thick and 2·52 metres high. A floor of pile framework ·475 metre thick (or deep) connects these side walls or abutments at the base. Some alterations in the details were made in the 30-metre radius curves.

As regards the stations, of which there are twenty-three along this first line, five different types have been adopted in their erection. For one thing, wherever feasible—and this applies to the greater number of the stations—the roof is an elliptic arch, considerably depressed (Figs. 7 and 9), of 14·14 metres span and 3·50 metres rise, connected at the springings by an invert of elliptic section, rendered with cement plaster 2 cm. thick, while the upper arch or dome of the tunnel has been faced with glazed or "opaline" tiles, thus giving them a healthy, decorative, and altogether pleasing appearance.

The station-platforms, elevated 85 centimetres above the rails, are 4·10 metres wide, and supported by small brickwork arches resting upon walls erected perpendicularly to the surface of the line.

In the case of seven other stations, to avoid the necessity of placing the rails below the level of the water-mains, the upper part has been formed with a metal flooring supported by masonry walls. This flooring is constituted of main girders, at right angles to the axis of the line, supporting string-pieces upon which are erected a number of small brickwork arches.

At the Lyons terminus (Fig. 10), which it is intended, in the near future, to use as a junction station, both for the "Circular" System, B, and for the Vincennes and Porte Maillot line, the main girders of the flooring which covers it are supported at their ends by masonry walls, and at their middle parts by a double row of cast-iron columns, placed along the axis of the platforms, each of which is 100 metres long, while the total width between the side walls is 23·90 metres.

FIG. 14.—ENTRANCE TO THE AVENUE DES CHAMPS-ELYSÉES STATION.

The Bastille station (Fig. 11) is uncovered, and, moreover, is the only one of its class in that part of the metropolitan line which has been in use since 1900. To build the viaduct and its approaches, the St. Martin Canal had to be covered over 40 metres of its width.

The three termini, at the Vincennes, Maillot, and Étoile gates (Fig. 12), com-

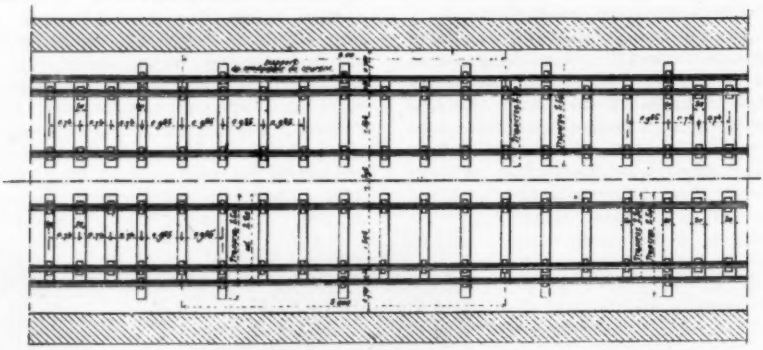


FIG. 15.—PLAN OF RAILS.

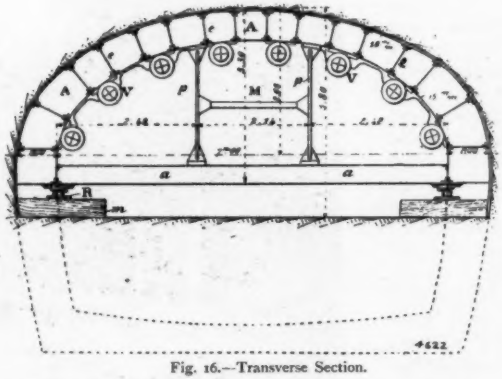


Fig. 16.—Transverse Section.

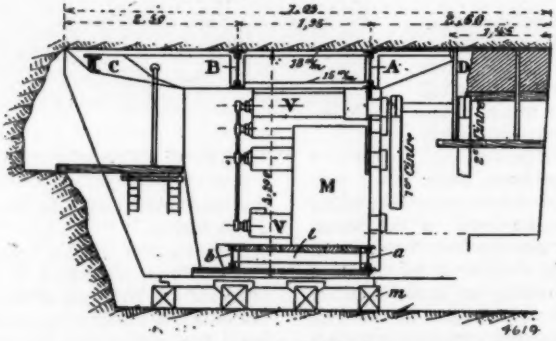


Fig. 17.—Longitudinal Section.

FIGS. 16 AND 17.—DETAILS OF CUTTING METHOD.

prise two arched parts, one for the arrival platform and the other for the departure platform, each connected together by a single-line circular gallery. Owing to this arrangement the incoming trains need only pass around the loop preparatory to travelling in the opposite direction.

Access to the Metropolitan Railway platforms is generally obtained by descending a staircase, from 3 metres to 3·50 metres wide, leading from the roadway to a subterranean hall in which the booking offices are situated (*vide* Figs. 5–9). Thence the passengers, by a similar though smaller flight of steps, may either reach the nearest platforms or cross a footbridge and ascend some steps leading on to the platforms on the opposite side, according as they wish to travel in one direction or the other. Some of the stations—the termini in particular — have two separate approaches connected with the arrival and departure platforms respectively. At most stations situated in the centre of the city the open air-holes in the road-pavement, and in street refuges in the middle of the road, are surrounded each by an iron guard-fence (Fig. 13).

At other stations the steps leading to the platforms, and forming the entrance to them, are approached by a very neat little lodge of somewhat stylish architecture (Fig. 14), designed by M. Hector Guimard, a Parisian architect. The decorative methods of this clever artist are based almost exclusively upon this guiding principle, viz. the "line" of texture (*la ligne*): thus, according to his view, each kind of material should be used in a manner which shall be in harmony with its natural texture or composition. In dealing with wood, for example, he follows the lines of the fibre, or nodosity, peculiar to each kind of wood; in using, say, stone or cast iron, he will adopt fuller and more bulky outlines; for wrought iron his forms will be angular and sharply defined, suggestive of the hammering to which the metal has been subjected at the forge. Guided by these theoretical principles, M. Guimard has succeeded in calling into existence quite a unique æsthetic manner.

With regard to the line itself, it consists of Vignoles steel rails, weighing 52 kilogrammes per running metre—15 metres long each — placed upon creosote-impregnated wood sleepers, the internal gauge being 1·44 metres (Fig. 15). At a distance apart of 3 metres, special 2·50-metre sleepers or cross-pieces—with the interposition of suitable insulators —support the conductor rails placed between the two lines for the purpose of providing the cars with current. Incandescent lamps are secured to the arch a little above springing line, being arranged lozenge-fashion, 12·50 metres apart, for a distance extending for 75 metres from the station in either direction, while, in the remaining part of the tunnel, they are placed 25 metres apart. As regards the stations with a metal floor, where the roof is not so well adapted for diffusing light, the illuminating plant is supplemented by more powerful incandescent lamps.

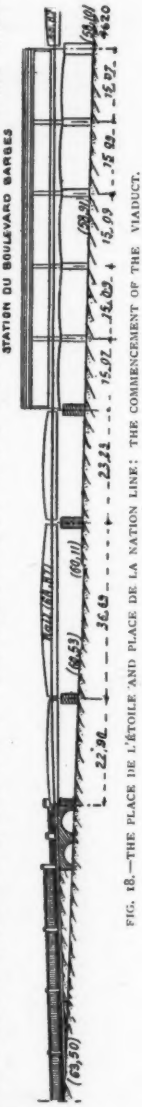


FIG. 18.—THE PLACE DE L'ÉTOILE AND PLACE DE LA NATION LINE: THE COMMENCEMENT OF THE VIADUCT.

It was not without difficulty that the work of constructing the first metropolitan railway line was carried out. In the first place, to avoid interfering with street traffic unduly, most of the work was conducted underground, save at the points where the intrados of the subway was too near the road-surface, while, in addition to that, the nature of the ground which had to be traversed added to the difficulties, of which I will endeavour to give a brief description from the data with which I have been furnished by the engineer, M. Biette himself.

FIG. 19.—THE PLACE DE L'ÉTOILE AND PLACE DE LA NATION LINE: VIEW OF VIADUCT DURING THE PERIOD OF CONSTRUCTION (MARCH, 1902).

At both ends of the railway system, the subsoil consists of "Beauchamps" sands, which are only covered with a thin stratum of Saint-Ouen marl north of the Place de l'Étoile. At or near the Étoile quarter these sands constitute a solid mass about 8 metres deep, resting upon the rough limestone marls, at the base of which there are some beds of rock. Throughout the central part of line *A* this species of marl is to be found, and here also it is covered by ancient alluvia from the Seine, which, in their turn, support certain banks formed at different periods, and varying in thickness accordingly. In fact, it was only, perhaps. in the neighbourhood of the two termini of the Metropolitan Railway that the line traced out passed through ground which by its nature was favourable to the conduct of the works. In the intermediate part it was necessary to carry out the masonry or brickwork in old embankments of generally but indifferent consistency. For the most part of the Rue de Rivoli they consist of loose, running rubble, intersected at frequent intervals by old buildings. Besides, the height at which the roadways run necessitated the construction of the flooring at a less gradient than the general surface of the underground line; this happened at three points, viz., Avenue Ledru-Rollin, Boulevard de Sébastopol, and Place de la Concorde—a conjuncture of circumstances which rendered the task of the engineers particularly arduous.

It was necessary, most of the time, to resort to the "shield" method for the construction of the tunnel from Vincennes to the Porte Maillot. But unlike the shield which had been devised in 1893 by Berlier for cutting the main sewers under the Seine (the sewer occupying the whole of the gallery which was being run), the new type of "shield," of which M. Chagnaud is the inventor, only covers the upper half of the gallery which is being cut. Figs. 16 and 17 are, respectively, a longitudinal section and a transverse section of the type of "shield" manufactured by the firm of Champigneul.* The main part of this apparatus

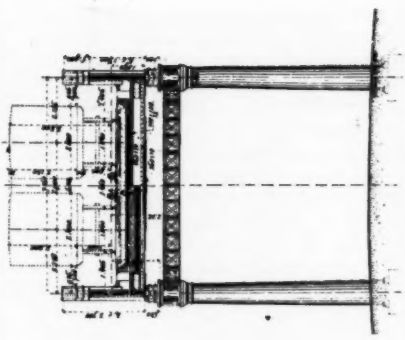


FIG. 21.—TRANSVERSE SECTION OF THE VIADUCT.

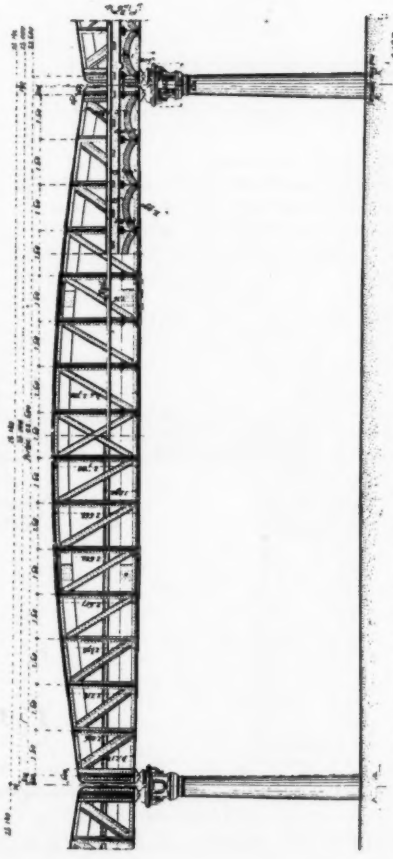


FIG. 20.—VIADUCT ON LINE B: ELEVATION AND LONGITUDINAL SECTION OF THE VIADUCT.

* Other shields, supplied by Messieurs Baudet & Donon, were also used; but I must refrain from describing them more fully, from lack of space.

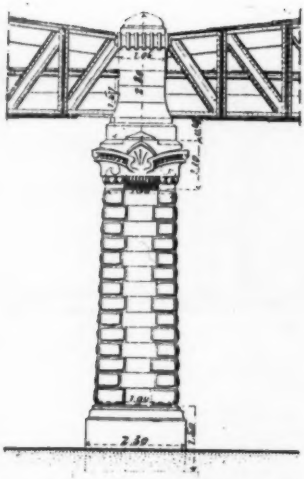


FIG. 22.—VIADUCT ON LINE B: VIEW OF MASONRY PIER.

consists of an iron-plate shell which fits the top part of the tunnel, and is stiffened by two arches *A* and *B*, formed by beams or girders placed 1·95 metres apart. At the front end, the shell extends to form the working compartment, stiffened by girders, as shown at *C*, and the "shield" terminates in the cutting edge. A floor is suspended from the front portion of the "shield" to facilitate the work of the men employed. The rear end of the "shield" terminates in a tail-piece *D*, 2·60 metres in length. The beams *A* and *B* are connected by longitudinal bracing *e e e*, while transverse girders *a* and *b* connect the ends. Besides, vertical members *p p* connect the braces with the curved girders, and string pieces *l*, Fig. 17, serve to support a floor of planks, upon which is erected the electric motor *M* operating the eight hydraulic jacks *V*, used to produce the advance motion of the "shield." The motor serves to operate a battery of pumps supplying water under pressure. The whole of the apparatus rests upon the ground, with the interposition of two special supporting rails *R*, which facilitate its sliding motion, and which themselves are supported by timber beams *m*. Necessarily the advance of the "shield" is dependent upon the stroke of the jacks—being in this instance one metre long. In the case of the Metropolitan Railway, the jacks abutted against metal arches placed in the rear, and were each capable of exerting 110 tons of pressure, equal to a total strain of 880 tons; although a pressure of 500 tons was really never exceeded at the point of attack. As the "shield" advanced, masonry was erected upon supporting arches or centerings, placed in the rear, and numbering thirty. As shown in Fig. 16, the excavation of the lower part (whereof the dotted lines indicate the masonry) was carried out by the usual methods.

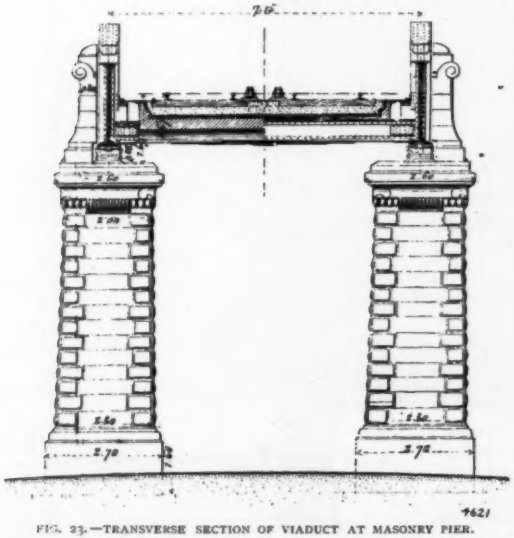


FIG. 23.—TRANSVERSE SECTION OF VIADUCT AT MASONRY PIER.

The subway was nearly throughout built with slow-setting cement concrete, prepared with pebbles and broken limestone; but in some places brick and stone masonry were adopted. For the arches, quick-setting Vassy cement was used. The rubbish was cleared away

by means of trucks or wagons drawn by animal traction, and electric light was used in illuminating the work underground. The whole of the works involved in the construction of the line A took seventeen months to be completed, which, in view of the obstacles which had to be overcome, was, after all, a short period. The first trains travelled between the Porte de Vincennes and the Porte Maillot in July, 1900.

I will now describe more cursorily the B line, whereof the portion between the Place de l'Étoile and the Rue de Bagnolet is now open for traffic (February, 1903). As, however, the tunnel is now entirely completed for the whole of this line, the remaining section will no doubt become available for public use in April or May, 1903.

As will be seen by referring to Fig. 1, this line extends along the outer circle of boulevards on the right bank of the Seine. The line which has been traced out to connect the Étoile with the Place de la Nation for the most part extends underground. However, at the points where it crosses the Eastern and Northern Railways it was necessary to build viaducts for a distance of 2 kilometres, to avoid having galleries or tunnels to cut at too great a depth, as this would have rendered the approach of the stations too inconvenient to the public.

Besides, the declivity of the surface of the road within the area under consideration, and the adoption of further comparatively steep gradients, permitted the distance, for which the central avenue had to be closed for traffic, in the transverse direction (owing to the viaducts) to be reduced to 118 metres on the Boulevard Barbès, and to 170 metres on the Boulevard de la Villette (Fig. 18).

The minimum free elevation of the viaduct above the level of the river banks is 20 metres, so that it exceeds the height of the public conveyances fitted with seats on their roofs, which now circulate in Paris, by 50 centimetres. Fig. 19 shows a section of the viaduct, erected by the Société Anonyme des Ateliers de Montreuil, on the Boulevard de la Chapelle, the view having been taken during progress of the works. Figs. 20 and 21 are corresponding elevations and longitudinal and transverse sections. The average span of the bays is about 22 metres, their ends resting upon the capitals of cast-iron pillars or columns, or upon stone piers, with the interposition of knee-jointed apparatus (Figs. 22 and 23).

Broadly speaking, the viaduct consists of the two girders, the bottom flanges of which support the flooring, and which, according to the width of span, are single, twin or braced girders. The main girders are delivered from the works in three sections or lengths, which are fitted and riveted together on the spot. A pump worked electrically actuates the hydraulic riveting machines, which bring a pressure of about 45 tons to bear upon each rivet-head. Travelling cranes of 15,000 kilogramme capacity raise these girders and place them in position on their supports. A machine of this class is shown in Fig. 19.

To reduce the noise and vibration the lines are, generally speaking, ballasted; although, in the wide span bays of the viaduct, they are supported by string-pieces direct, so that the weight of the structure, and consequently the expense it involves, may be less. Where ballast is used, cross-ties, connected by small brick arches filled in with concrete, constitute the flooring. Upon the crown of each of these arches there is erected a low masonry wall running parallel to the axis of the railway line, and all the brickwork is rendered with cement mortar 2 centimetres thick, so as to form water-tight trenches, in which the ballast is placed. The rain-water is carried off by gutters or waste-pipes built at intervals in the interior of the piers supporting the whole of the structure.

Where the lines are supported by string-pieces the flooring is formed of inter-ties fitted to the river-bank girders, on to which are secured the stringers which serve to hold the oak sleepers supporting the rails. The flooring is covered externally with corrugated iron plates.

The underground sections of line *B* have a sectional outline similar to that of line *A*; but in order to join the tunnel to the viaduct, trenches 6·70 metres wide are made use of for a certain distance, being

partly covered by a metal flooring, where the difference of elevation between the level of the line and the roadway admits of this; and partly open, where such is not the case.

Twenty-three stations (see Plan 1) are distributed over the distance between the Étoile and the Place de la Nation, eighteen of which are arched, one having a metal roof (viz., the Rue de Rome Station), and four being built over railway bridges or viaducts (as in the Rue de la Chapelle and Rue d'Allemagne Stations). As the total length of line *B* is 10 kil. 539 metres, the average distance from station to station is under 500 metres.

Great latitude was given to the contractors for the several sections of the work, with regard to the methods of construction of the masonry required for this line; and, accordingly, these methods have varied widely, though none of them exhibited any peculiarity deserving of special notice. The "shield" tunnel-cutting method was not adopted for this line. But the work-yards, which for the underground works were merely shafts or pits for the removal of detritus and the supply of materials for the masonry, were subjected to certain restrictions by the authorities, so that any blocking of the public thoroughfares might be avoided.

(To be concluded.)

Alloys as Revealed by Modern Research.

By PERCY LONGMUIR.

OWING to the vast number and variety of alloys resulting from the union of two or more dissimilar metals, the term "alloy" is an exceedingly difficult one to confine within narrow limits. Individual investigators have, in all times, adopted their own interpretation, and hence it naturally follows that the word alloy has become one of general rather than particular acceptance in the metallurgical world. Alloys are, in general, produced by fusion of the constituents, the resultant liquid being poured into a sand or metallic mould, and allowed to solidify. They may, however, be produced by electro-deposition, by compression of minute particles of the constituents, or, in certain cases, by penetration. An example of the latter method is that of the diffusion of carbon through red-hot iron, as in the cementation or converting furnace, the product of which is a blister steel. Metals, or a metal and metalloid in association, yield in the majority of cases properties not possessed by either of the constituents, and hence, in industrial operations, pure metals are of comparatively limited application. However, apart from an increase of mechanical or other properties, alloying is practised in certain cases to permit the use of a costly metal in practical industry. The study of these various alloys has been continued through many ages; it is to-day one of absorbing interest to the metallurgist, and the accumulated records of so many investigators constitute a bulky enrichment to the literature of metallurgy. Nevertheless, though so much good work has been done, there is still an immense field, large areas of which have been untouched, for original laborious research. It is quite natural that on a subject of so vast an extent many conflicting theories should be advanced, and even though some of these theories regarding the effect of an addition of a metal or metalloid to another metal may have been very hypothetical, they have, at any rate, served a useful purpose as stages in the evolution of metallurgical knowledge. It is our present purpose to examine a tendency of modern thought in this direction, and as far as possible avoiding technicalities, to indicate generally the trend of present experiment and research.

The new features or properties of a metal brought out by the effect of an "added element" may be readily understood when that addition is an appreciable quantity, and sufficient to saturate the mass. Radical changes in physical properties are in such a case easily apparent; but when the addition consists of a mere trace, producing a most vivid effect, the phenomenon then assumes a more complex form. The effect of traces of a foreign element is, perhaps, most familiar in the case of iron. A few tenths of one per cent. of carbon produce an immense change in the character of the metal. A few hundredths of one per cent. of sulphur associated with the iron determine its success or failure in industrial life. It is in no less degree the case with other metals, the presence of the merest trace of bismuth in copper producing remarkable differences in mechanical and electrical properties. The enormous influence exerted upon a mass of metal by the presence of a trace of another element is truly marvellous, and out of all proportion to the mass in which it is distributed. The very minuteness of this added trace is alone sufficient to prove that the change in properties is not the result of any inherent virtue of the element added. There must be other energy at work, and in examining possible causes, the following are selected from a mass of contemporary theory, evidence and experiment.

The added element may combine with a portion of the metal to which it is added and form a definite chemical compound. This compound may diffuse evenly through the mass, it may occur in isolated areas, patches, or plates throughout the structure, or it may be found enveloping the crystals of pure metal. The added element may, on the other hand, diffuse evenly through the metal when liquid, but as solidification takes place the metal may crystallise in a pure state, rejecting the addition—also in a state of purity. In the cold metal the added element would then be found in a free state ar anged along the lines of crystalline junction. If traces only were present such an arrangement would not be seriously detrimental, but supposing the bulk to be sufficient, each individual crystal of the metal would become encased as it were in an envelope of foreign matter, and crystalline contact impaired to the extent of the thickness of these envelopes. This structural arrangement is synonymous with the one just described, that in which a compound, formed by a combination of the added element with a portion of the metal, envelopes a pure crystal.

Dissimilar metals or a metal and a metalloid in association may, when in a liquid state, be regarded as solutions, and they then offer certain points of comparison to ordinary saline solutions. In the latter, as the temperature falls precipitation takes place. This precipitation is affected by the strength of the solution—definite and pure crystals falling out and leaving the "mother liquor" still liquid. Still further reduction in temperature results in the solidification of this mother liquor, and it is worthy of note that this point is a fairly constant one. The solidified solution consists of pure crystals and solidified grains of the mother liquor in juxtaposition. The mother liquor in such a case is regarded as the cryohydrate, and its analogy in the case of a metallic solution receives the name of "eutectic," eutectic denoting the frozen mother liquor and being the last portion of the metal or alloy to solidify.

As a rule, all metallic combinations have a lower melting point than that of the mean of their constituents. Assuming that the effect of a trace of an added element is to combine with the metal and form a definite compound, it is evident that the bulk of this compound is insufficient to saturate the mass. Such a metal would, on cooling, therefore, speaking broadly, present two distinct points of solidification, namely, that of the pure or free metal, and that of the compound or "eutectic." The crystals of free metal may, in the solidified alloy, be regarded as in a state of suspension in the eutectic, or *vice versâ* if the volume of the eutectic be greater than that of the free metal. A fact of importance is that the tenacity and ductility of such an alloy are represented by those of the eutectic. If the eutectic possess brittle properties, then fracture will readily occur along these areas or membrane, or in whatever form the eutectic is found in the metal. Hence individual crystals may be ductile and the mass brittle, provided those crystals are surrounded or enveloped in a fragile cementing eutectic. Thus, silver associated with a trace only of bismuth will in mass be brittle; yet, at the same time, individual grains, if isolated, are found to possess the characteristic ductility of pure silver. The enormous change in mechanical and electrical properties of copper when also associated with a trace of bismuth are to be explained in a similar manner.

Speaking generally, metals of high melting points are fairly tenacious when compared with those of lower melting points, ready examples of which are found by a contrast of iron and lead. It is also found that if the addition of an element to a metal tend to raise the solidification point of the eutectic an increase of tenacity is the result, whilst if the effect of the addition be to lower the freezing point of the eutectic the tensile strength is impaired. In all probability this reduction of tenacity bears a direct ratio to the lowering of the solidification point of the eutectic. In estimating the effect of a trace of an added element, individual action may, in the majority of cases, be ignored and the effect of the addition in association with a portion of the metal be considered. This association may result in a cementing material, the cohesive force of

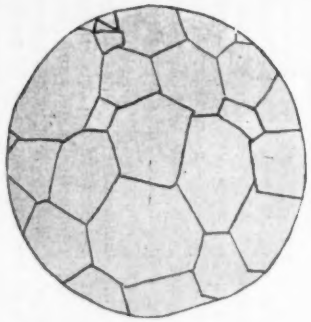


FIG. 1.—STRUCTURE OF PURE METAL MAGNIFIED 100 DIAMETERS.

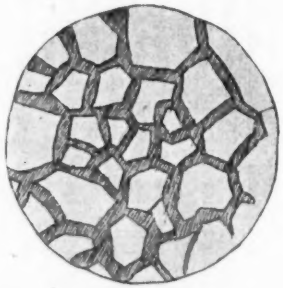


FIG. 2.—THE EFFECT OF MINUTE ADDITIONS OF IMPURITY. MAGNIFIED 100 DIAMETERS.

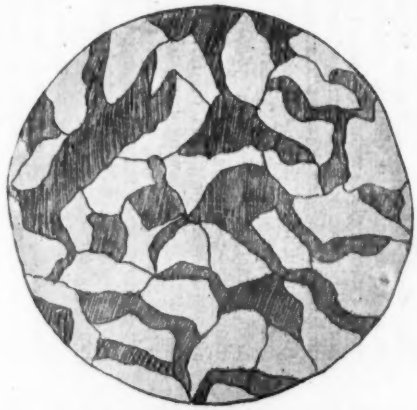


FIG. 3.—IRON ASSOCIATED WITH '2 PER CENT. CARBON. MAGNIFIED 600 DIAMETERS.

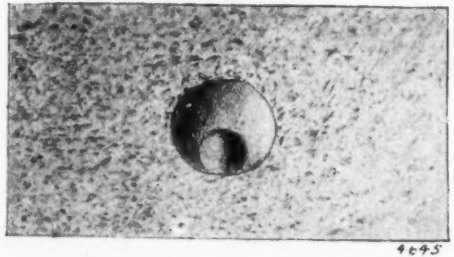


FIG. 4.—FRACTURE OF METAL SHOWING CAVITY OR BLOWHOLE AND INCLUSION OF EUTECTIC.

which is equal to that of the crystals themselves, resulting in a tenacity equal or superior to that of the original metal. On the other hand, the result of such addition may be a very brittle cementing material, and the tenacity would of course correspond to the brittleness of the eutectic.

Metals when in a state of purity crystallise on solidification into irregular polyhedral crystals. A section of such a metal will, after preliminary polishing and etching, present at a suitable magnification a series of crystalline junctions, the structure thus shown consisting of a network arrangement. The size of these crystals varies with the rate of solidification, slow cooling favouring the production of large and well-developed crystals. The structure shown in Fig. 1 is actually that of gold magnified one hundred diameters, but it is also typical of pure iron or pure copper. If to this gold 0·2 per cent. of lead is added, a structure resembling that shown in Fig. 2 is obtained. No better illustration of the effect of a minute addition of one metal to another can be given. The lead, most probably in association with a certain amount of gold, forming the eutectic has arranged itself as a membrane between the crystals of free gold. This structure is typical of many obtained by the addition of minute quantities of one metal to another, and is very nearly an exact representation of the structure developed in copper by the introduction of ·2 per cent. bismuth. An examination of Fig. 2 reveals the manner in which individual crystals of a metal may be ductile and its mass brittle, and it is quite evident that the tenacity of bars of the metal is represented by that of the cohesion between the cementing membranes and the crystals. This will be the more readily seen by supposing Fig. 2 to be translated into the solid. The envelopes of the eutectic effectively isolate each crystal, and if these envelopes be brittle or of low cohesive power, then the mass will be, as already stated, readily fragile. Fig. 3 represents a typical structure of iron, associated with 0·2 per cent. carbon. As stated earlier in this paper, an added element may form a definite compound, areas or patches of which may exist contiguously with the crystals of pure metal. This effect is shown in Fig. 3, the dark areas representing a definite carbide of iron, intermingled with crystals of free iron. This free iron is known as "ferrite," the carbide receiving the term "cementite." An association of these two constituents results in the presence of "pearlite." At a high magnification—from 300 to 500 diameters—pearlite is found to consist of alternate layers or plates of ferrite and cementite. In drawing comparison between the structure of steel and that of other alloys, steel may be regarded as an alloy of ferrite and cementite, pearlite forming the eutectic.

The structural arrangements resulting from the addition of 0·2 per cent. of an added element is well shown in the foregoing, and it naturally follows that any increase in the content of that addition results in a corresponding alteration of structure. Continuing the increase, a point is reached when the crystals of free metal disappear, and are replaced by others of various compounds or eutectics. In the case of iron, this is reached at about 0·9 per cent. carbon, ferrite having then entirely disappeared from the structure. It has been recently shown that in tin-copper alloys a similar point is reached with tin in association with 1 per cent. copper, crystals of free tin having been replaced by compound ones. General alloys crystallise immediately on solidification; alloys of iron and carbon are, however, an exception to this rule, steel not crystallising until a temperature between 800 degs. C. and 700 degs. C. is reached, which is considerably below the solidification point.

The effect of added traces, therefore, possesses an interest far wider than that of a merely scientific one. Impurities present in a metal—even when in minute quantities only—may, by a structural arrangement, such as that shown in Fig. 2, render an otherwise ductile metal into one of comparatively little industrial application. Bismuth and copper, already quoted, illustrate this statement. In the case of a steel of low sulphur content, even in one sufficiently low to meet any stringent chemical specification, it is

possible in certain, though probably isolated, cases, for even that low quantity to render the steel useless. Supposing that conditions favour the formation of a definite sulphide of iron, or if manganese be present in the steel, then sulphide of manganese — the relative volume thus occupied by these sulphides is out of all proportion to that occupied by the free sulphur. Carrying the supposition a little further, and assuming that conditions favour the segregation of this sulphide into continuous areas or strings, then brittle lines are developed, along which, at any favourable moment, fracture will readily travel. In an explanation of this type may be found a solution of the manner in which fracture occasionally occurs in metals of otherwise good chemical composition.

Turning to the beneficial effect of an added element, a typical illustration may be found in the case of arsenical copper. Fire-boxes constructed from such a copper possess a longer working life than do those made from arsenic-free copper. It is found in actual practice that copper alloys, when used in positions in which pressure and temperature are present—as, for instance, certain classes of boiler fittings —yield better results when associated with a trace of arsenic. Arsenical copper, tested at a temperature of 300 degs. Cent. by the late Sir Wm. Roberts Austen, yielded a tenacity of 12·6 tons per square inch. Ordinary copper at the same temperature yielded 9·38 tons per square inch, this increase of tenacity over that of ordinary copper at the temperature quoted offering an explanation of the increased life of locomotive fire-boxes when made from arsenical copper. It also accounts for the addition of a trace of arsenic by brass founders to gun-metal intended for use in the production of high-pressure fittings. In the latter case the presence of arsenic would seem to raise the solidification point of the eutectic, thereby increasing the strength of the alloy and its application to positions in which temperature and pressure are associated.

In applying the foregoing statements to industrial alloys, which are generally contaminated with varying amounts of one or more impurities, some idea of the importance of their effect on structural arrangement will be attained. In the case of steels—in which are always present varying amounts, according to the quality, of sulphur and phosphorus—the relative effect of the sulphides and phosphides, if formed under favourable conditions and segregated in the manner indicated, can be easily estimated. It has been shown that easily fusible compounds or eutectics present in a metal of comparatively high melting-point tend to affect that metal detrimentally. These eutectics may be isolated, and are often met with in actual practice. A bar of phosphoretic steel, if heated, will, under certain conditions and on reaching the requisite temperature, exude tiny globules of phosphide. In connection with these exudations it is of interest to note that wrought iron contaminated with phosphorus is easier to weld than iron of a low phosphorus content—speaking of course of the mechanical operation of welding, not the strength of the weld. It may be that these extrusions of a fusible compound assist in promoting a metallic union of two pieces of iron. If an ingot of gun-metal be heated, exudation of the eutectic may be observed in a similar manner; and it is of no little interest to watch these metallic globules trickling from an otherwise solid ingot. This phenomenon is most readily observed by watching the heating of an ingot preparatory to its liquefaction. The alloy, phosphor-bronze—consisting of 90 per cent. copper and 10 per cent. phosphor-tin —rapidly passes from a liquid to a solid state; that is, once solidification commences it proceeds—in comparison with other copper alloys—very quickly.

Yet, in spite of this, some time after solidification—in fact, when the alloy has reached a black heat—bright silvery and liquid exudations may be observed. These when cold take the form of small buttons or shot, and are found wherever an opportunity for extrusion occurs, as, for instance, in cavities or fissures of the casting resulting from contraction. An example of such is figured (Fig. 4). The writer was fortunate enough to break the metal just across the cavity and preserve the shot of eutectic.

These shots are are also occasionally found at the runner head of a casting, appearing when a black heat is attained and after feeding has ceased. This has resulted in the practice of weighting the heads, that is, sprinkling over sand and putting on a weight, in order to prevent this rejection of eutectic. With large castings, after they are, to use a technical term, "fed up," the feeding heads are effectually frozen up with water, in order to attain the same purpose. A noteworthy example of this rejection of eutectic, in the case of a phosphor-bronze casting, is within the writer's recollection. One part of a casting, consisting of a slightly curved plate, about 6 ft by 5 ft. by 3 ins., had, in process of cooling and contraction, left the face of the mould by about $\frac{1}{16}$th of an inch. Examination revealed the fact that this side of the casting was studded with small shot, varying in size from a pin-head to that of bird-shot. The eutectic had in this case travelled from the interior to the exterior, and the casting in contracting away from the face of the mould had left room for its extrusion.

These conclusions fully endorse the importance of the structural or crystalline formation of an alloy, and though this formation is determined in large measure by chemical composition, it is also influenced to some extent by thermal or physical causes. The scope of this paper does not warrant an examination of the effect on structure of rolling, forging, or annealing, but the beneficent effect of such treatment is generally recognised. Other causes limiting the structure, and at the same time influencing the mechanical properties are varying casting temperatures and pressures, and it must be confessed that the reasons as yet advanced for the effect of either of these latter causes are still in a very hypothetical region.

300-K.W. Triple-Expansion Engine at Middlesbrough Electricity Works.

THE generating plant of the Middlesbrough Electricity Works was constructed to the specification of Mr. Robert Hammond, the contractors for the engines and dynamos being Messrs. Davy Brothers, Ltd., of Sheffield.

It consists of one 300-kilo-watt vertical triple-expansion Corliss steam engine, specially designed and constructed by Messrs. Davy Bros., Ltd., for driving a dynamo direct; one 100-kilo-watt high-speed compound engine, driving two 50-kilo-watt dynamos direct; and one motor generator for charging accumulators. The dynamos were supplied by Messrs. P. R. Jackson & Co., of Salford, Manchester, and the 100-kilo-watt high-speed engine by Messrs. Browett, Lindley & Co., of Patricroft, Manchester.

The design of the 300-kilo-watt engine, the description of which forms the chief feature of this article, constitutes a new departure in the economy of electric generating plant, and combines the advantages of the slow-speed Corliss engine with those of the high-speed or quick revolution engine, and was designed with a view to obtaining the maximum economy per kilo-watt delivered at the switchboard.

The engine is vertical, and has cylinders

FIG. 1.—VIEW OF THE TRIPLE-EXPANSION DAVY ENGINE.

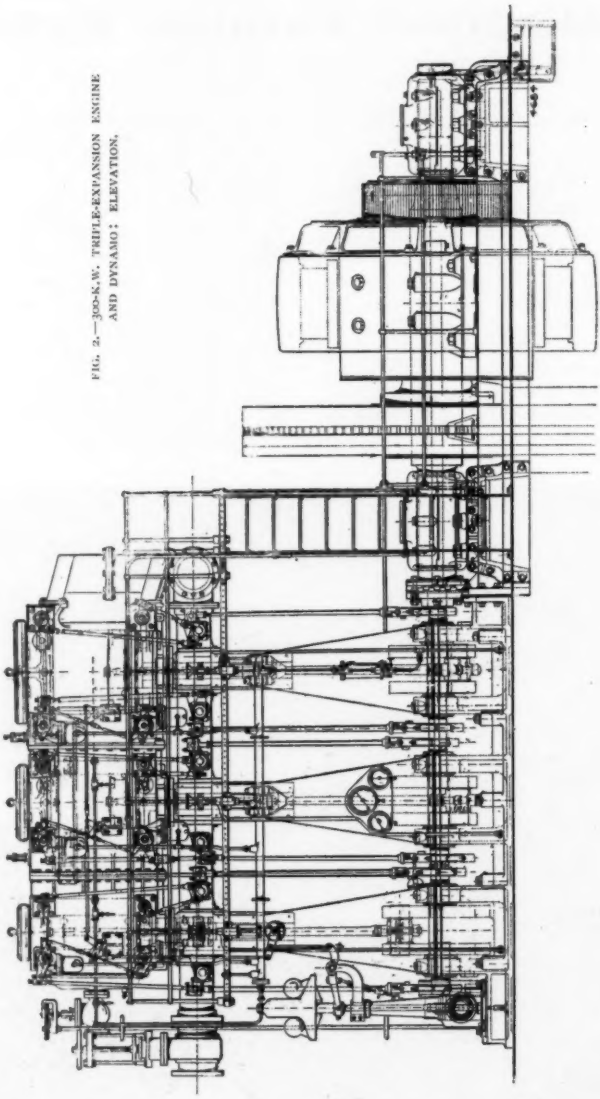


FIG. 2.—300-B.W. TRIPLE-EXPANSION ENGINE AND DYNAMO: ELEVATION.

12½ ins., 20 ins. and 30 ins. diameter by 30-in. stroke, running at 120 revolutions per minute, the steam pressure being 160 lbs. per sq. in. A speed of 120 revolutions per minute may appear high for Corliss valves with trip gear, but the working of these engines has been so satisfactory after having run continuously for two years without any appreciable wear that it has led to the construction of Corliss engines running up to 140 revolutions.

The conditions laid down in the contract were that it was to develop 300 kilo-watts at the switchboard with 160 lbs. in the steam chest, and a vacuum of 24", and be capable of developing 350 kilo-watts in an emergency. It was also to be capable of working non-condensing without any alteration to the valves or gear. Although the most economical load of the engines is 75% of the full power, or 225 kilo-watts, the guarantee was based on the consumption at full load. In consideration of the amount of penalty or bonus at stake, no expense in design and construction which would increase the efficiency was spared. The accompanying illustrations clearly indicate the design and construction of these engines.

The steam cylinders (Figs. 2 and 3) are bolted up to one another and carried by three pairs of standards. The Corliss valves are all double ported, and have consequently a very short travel, a matter of the very greatest importance with trip-gear working at 120 revolutions per minute, besides which the speed of opening is greatly increased. The cut-off gear to all three cylinders is under the control of the governor. The range of cut-off in the high-pressure cylinder is from zero to 75%

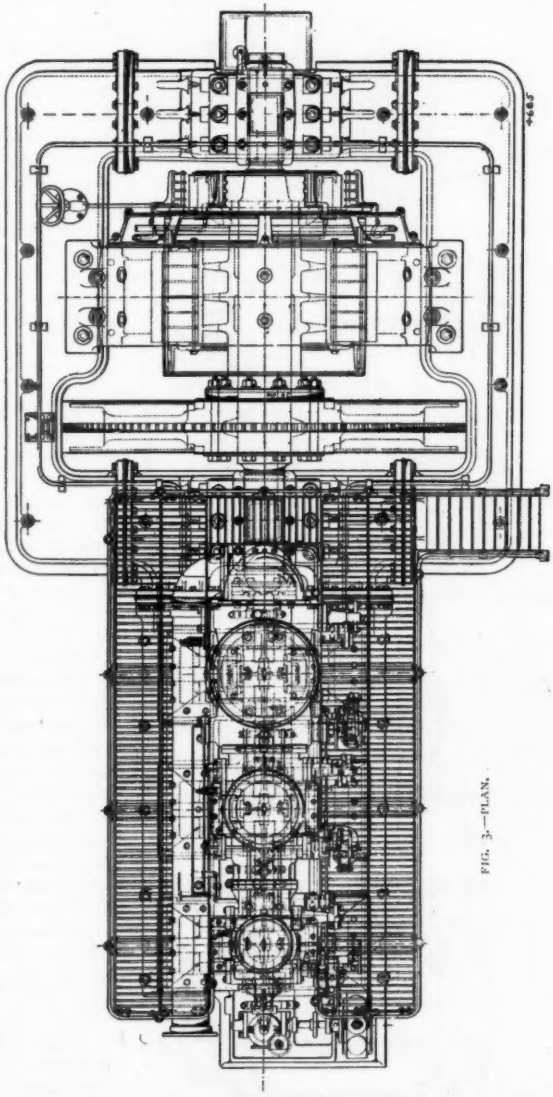


FIG. 3.—PLAN.

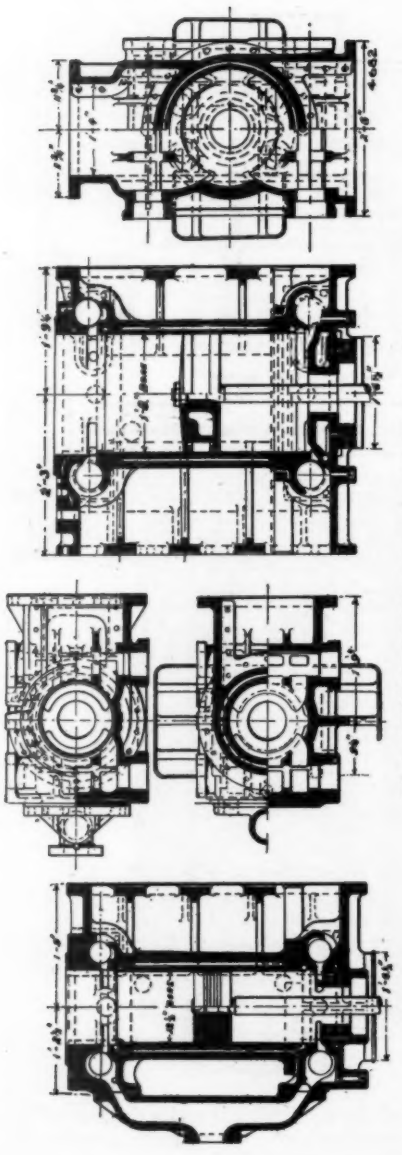


FIG. 4.—DETAILS OF INTERMEDIATE AND LOW-PRESSURE CYLINDERS.

of the stroke. The valve gear is fitted with steam-closing cylinders and air cushions, as these are found to be more reliable than either vacuum closing cylinders or springs; and they have also the advantage that the closing pressure is constant, no matter at what point the trips are released. Moreover, the closing pressure can be regulated to a nicety. The exhaust valves are driven through wrist plate motions; this allows the valves to remain practically stationary on their seats when closed, and when the pressure of the valves on their faces, due to the steam pressure within the cylinders, is at a maximum, reduces the wear and friction of the valves to a minimum. The valve spindles are of special forged steel, and drive the valves by large palm ends. The spindles are fitted with self-adjusting metallic packings.

The cylinders (Fig. 4) are not steam-jacketed, but are fitted with renewable liners of special hard cast iron. The surfaces of the pistons and cylinder covers are turned perfectly level and smooth in order to reduce the clearance volume and surface to a minimum. The packing rings of the high-pressure piston are of a friction-less type, suitable for the highest pressures; the intermediate and low-pressure pistons are fitted with Messrs. Lockwood and Carlisle's patent rings and springs.

The piston rods are forged from special high carbon steel, $2\frac{5}{8}$ ins. in diameter, secured to the crossheads by taper cones and forged steel nuts. The stuffing boxes are provided with United States metallic packing.

The crossheads are of forged steel, each with two crosshead pins, $3\frac{1}{4}$ ins. in diameter by $3\frac{1}{2}$ ins. long. The slipper guides are of cast iron, rigidly bolted to the crossheads, and are lined with white metal. The slide bars are of a special mixture of cast iron, accurately surfaced; they are capable of accurate adjustment, and are provided with water circulation.

The connecting-rods are forged from special steel, the top steps of phosphor bronze, and the bottom steps of cast iron, lined with white metal.

The crank-shaft is of forged steel of the built-up type, with balanced crank webs, carried in six bearings $6\frac{3}{4}$ ins. in diameter

by 8 ins. long. The crank-pins are 7 ins. in diameter by 9 ins. long.

All the working parts are lubricated from an overhead tank fixed on the upper platform of the engines. This tank is fitted with a row of drop sight feed lubricators, connected by polished copper pipes leading to the various parts requiring lubrication.

The generator was supplied by Messrs. P. R. Jackson & Co., of Salford, the armature being mounted, together with a fly-wheel of 17 tons weight, on a forged steel shaft 19 ins. in diameter in the body, carried by two bearings, that next the engine being 14 ins. in diameter by 32 ins. long, whereas that outside the commutator is 12 ins. in diameter by 32 ins. long. The connection between the engine crank-shaft and the dynamo-shaft is by a special coupling, which will allow the crank-shaft to run out of line with the dynamo-shaft. Messrs. Davy Brothers prefer this arrangement to that of the American practice of making an abnormally large crank-shaft of sufficient strength to resist the severe strains set up when the crank-shaft and generator bearings get out of line with one another. The coupling is not intended to allow for large differences in alignment, but it is so constructed that the slightest variation is at once discernible, whereas when the solid coupling is used, or where the outer crank-shaft bearing serves also for the fly-wheel bearing, the first indication of any want of alignment is too frequently the failure of the crank-shaft.

The table shown gives the result of a test carried out on behalf of Mr. Hammond.

The result of the tests of this engine—viz. one kilo-watt hour delivered at the switchboard for 19·55 lbs. of feed-water measured into the boiler—proves that it is one of the most economical for its size which has ever been put to work.

This type of engine has proved to be possessed of many advantages, especially as regards fuel economy, and in that, on account of its comparatively high speed,

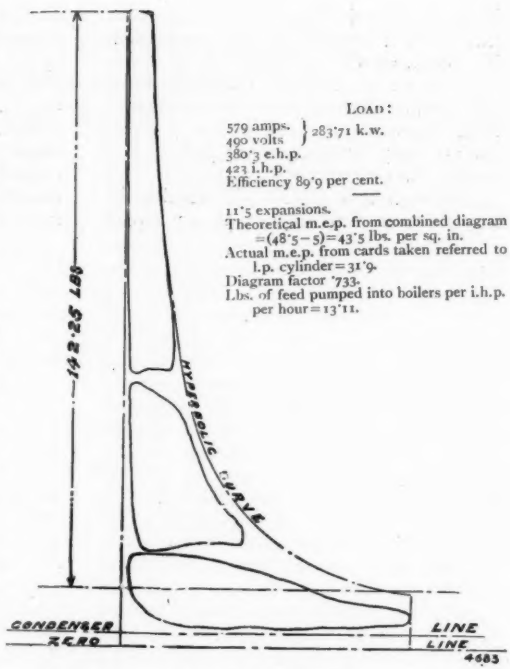


FIG. 5.—COMBINED DIAGRAM.

Table.

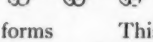
Date of test		June 23, 1902
Duration of test		4 hrs. 8 mins.
Weight of water evaporated by boiler in lbs.		25,974
K.w. per watt-hour meter ...	1,195	
K.w. per 1·2-per-cent. slow meter	14·34	
Total k.w. generated		1,209·34
Average k.w. per hour		292·58
Pounds of steam per k.w. ...		21·47
Average steam pressure... ...		158·5
Average vacuum...		19·53
,, speed		1,17
Deduction because of low vacuum ... 24·0		
19·53		
4·47 × 2 =		8·94 per cent.
8·94 per cent. of 21·47 lbs. ...		1·92
Nett lbs. of steam per k.w. ...		19·55

it is small, and therefore less expensive than Corliss engines of the usual type. The small number of expansions of steam (10 to 12 at normal load) in three cylinders renders cylinder condensation of small importance, and altogether removes the necessity for costly steam jackets and intermediate reheaters.

Although this engine will develop its normal load with only 10 to 12 expansions, it has a very large margin of reserve power for overload. This result is attained by the use of a patent special radial valve-gear fitted to the high-pressure cylinder, which controls the cut-off from zero to almost the end of the stroke; so that if steam is cut off at about half-stroke for normal full load, there is still a very large reserve of power for either emergencies or for working temporarily non-condensing.

Gas-Engine Valve Gears.

By CHARLES HURST.



In the present article the obsolete forms of gas-engine valves will be neglected, attention being confined solely to the mushroom type of valve, which has now practically displaced all other types. The defect of slides was that they suffered from abrasion, and soon became grooved and scored, and the small ports were very liable to become choked up. The Beau de Rochas cycle of operations is by far the most common, and is, in fact, at this present time the only commercially successful one. Unless otherwise stated, this cycle, or a modification of it, is referred to in the present article.

In most modern gas-engines there are four valves to each cylinder to perform the cycle of operations, whose functions are as follows:—The gas-inlet valve, admitting the charge of the suction stroke; the air-inlet valve; the ignition-timing valve, making communication between the compressed charge and the ignition tube; and the exhaust valve, controlling the exit of the waste gases. In some of the small commercial engines gas-inlet and air valves are automatic, and the ignition valve is dispensed with, the charge being fired by the act of the piston, the compression stroke forcing the mixture up to a certain height in the hot tube, the length of which is adjusted so that explosion occurs when the piston is at the end of the stroke.

Following on the lines usually adopted when dealing with the valve gear of steam-engines, the sizes of the valves and area of passages are first to be considered. In determining the area of the air-inlet pipe and passage, a calculated mean velocity of 90 ft. per second may be allowed for, due to the piston's displacements.

Therefore if A = area of cylinder,

P = mean piston speed in feet per minute,

The area of the air-inlet pipe and passages = $\frac{A \times P}{60 \times 90}$.

This velocity is low; but after engines have been working for some time a deposit forms upon the surface of the passage between the valve and the cylinder which contracts the area. In those engines in which the inlet valve opens directly into the cylinder (vertical engines are commonly so arranged), the above remark will not of course apply. The area of the opening due to the lift of the valve itself may be somewhat less, because it is not subject to diminution from deposit, and because the length of the contracted part is very small; consequently a mean velocity of 100 ft. per second may be allowed, calculated on the maximum lift of the valve.

The size of meter required—that is, the number of 16-candle-power lights a meter will supply, and which number is usually marked thereon—may be found as follows: Brake horse-power $\times 3{\cdot}4 + 5$.

Since the rule does not take into account the gas consumption per brake horse-power, it is only approximate, and latitude in either direction is admissible. The size of meter may also be found by assuming a probable gas consumption and allowing 6 cub. ft. per size of meter.

Diameter of gas-supply pipe in inches = brake horse-power $\times {\cdot}027 + {\cdot}75$, or size of meter in number of lights $\times {\cdot}008 + {\cdot}75$.

The exhaust passages may be calculated on a mean velocity of 80 ft. per second and a mean velocity of 95 ft. per second past the valve face, calculated on the maximum lift and the piston's displacement.

In tracing the action of the various valves of gas engines, it is somewhat difficult to devise a diagram which will show the complete cycle clearly and conveniently. This arises from the fact of the cam-shaft running at half the speed of the crank-shaft. The annexed diagram (Fig. 1) illustrates the action in as clear a manner as it seems possible; and, as will be shown later, it is extremely

useful when designing the cams. Starting at *A*, the air and gas valves open as the piston makes the suction-stroke, and both air and gas flow into the cylinder, the former until the crank has gone six degrees on the return or compression stroke. At first sight it may appear that this is a faulty action, and that the proper point for the closing of both air and gas valves is at the dead point *B*. At *B*, however, air and gas would still be flowing into the cylinder by reason of the momentum acquired in an earlier part of the stroke, and for a short period would flow in a direction contrary to the motion of the piston. The exact point at which the mixture would commence to return past the gas and air inlet valves depends on many circumstances, such as the speed of the piston, the length and form of the air-pipe leading to the air valve. Experiment alone can determine the point. In an engine of the writer's design, which had a cylinder 5 ins. diameter, piston speed 288 ft. per minute, air-suction pipe 4 ft. long with one easy bend, and a calculated mean velocity of 70 ft. per second for the inrushing air, light springcards taken near the air valve appeared to show that the return flow commenced at 12 degs. from the beginning of the compression stroke, or $\frac{1}{120}$th of a second after the reversal of the piston. Probably the return was before this, but the indicator was not delicate enough to show it. The engine possessed some features which were bizarre rather than successful, but the parts concerned in the above experiment were similar to ordinary gas-engines. The object of closing the gas valve before the air valve is to avoid the possibility of gas escaping down the air pipe. In a Cycle gas-engine making 172 revolutions per minute, the long stroke being $8\frac{1}{4}$ ins. and the short stroke $6\frac{7}{8}$, the maximum power was obtained when the air valve closed $\frac{5}{16}$ of an inch after the beginning of the compression stroke. In some engines the air-valve is opened slightly before the beginning of the suction stroke, in order to give a full opening early in the stroke. Reverting to the diagram, it is seen that, at *B*, the compression stroke begins, all valves being closed except in the case of starting, when the exhaust valve may be held open until half the compression stroke is completed, this action being shown by the vertical etch-lines in the diagram. The object of this is to ease the compression at starting, when the engine has to be pulled round by hand or impelled by a self starter. In addition to this, the opening of the timing valve is delayed for some 5 degs. after the crank has passed the centre, in order to obviate the possibility of the engine making a premature fire, thus starting in a reverse direction and injuring the attendant. At *C*, the ignition-timing valve opens. This point also is settled by actual trial on the engine. The power stroke is then made, and at *D*—about 82 per cent. of the stroke—the exhaust valve opens, and remains so until the piston has completed its in-stroke. Shortly after the opening of the exhaust-valve, the timing-valve closes, as shown at *E*. The closing of the exhaust-valve completes the cycle, and the piston begins to draw in a fresh charge.

The above action may be taken as the type of most engines of moderate size, but the valve gears of many engines differ from this action materially. In some, notably in the 1900 Campbell engine, one valve serves for both air and gas inlet, and this valve is not operated mechanically, but by means of the suction of the piston on its outward stroke, and instead of the cut-out motion operating on the gas valve, the exhaust valve is held open during idle strokes. In this example, and in some others, no timing valve is used. The Westinghouse engine operates on the lines of the diagrams, but there are no idle strokes. The quality or richness of the charge is not varied after once being decided on, but only its amount. This is accomplished by admitting the best proportion of air and gas into a box or retainer valve, where the two become well mixed. The cylinders draw their charge from this chamber past a throttle valve, in a manner almost identical with the throttle-valve arrangement of a steam engine. In others, the proportion of gas to air is varied, the quantity of the charge being constant at all times, there being no idle strokes. This method

of working introduces a difficulty in the firing of the charge, and electric ignition seems to be the only satisfactory plan. When this system of governing is adopted, special arrangements have to be made to ensure certainty of firing. A plan that has sometimes been adopted is to admit the air and a small portion of gas at the early part of the suction stroke, the bulk of the gas being admitted just before the end of the stroke. By this means the charge is rich in gas round the region of the hot tube, and there is, consequently less chance of a miss-fire on light loads. This matter will be reverted to later on. It may here be stated, however, that a most interesting example is found in the gas engines at the Belfast electric-lighting station.

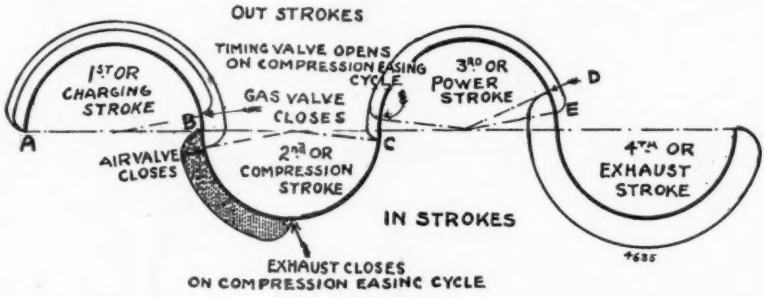


FIG. 1.

In designing the cams to effect the operations shown in Fig. 1, the considerations which determine the forms are a smooth-working shape, giving a rapid action. So far as smoothness in working is concerned an eccentric is the best possible form, but in addition to its action being sluggish it is unsuited to the action of gas engines, since if the rollers were always in contact with it there would be no period of rest, and the timing of the various valves could be obtained by clearance only. As in the case of steam-engine cams and rolling levers, a slow motion at the instant of contact is necessary to quiet action, but after contact has been made the opening may be as rapid as any easy form of cam will permit. What applies to the opening of the valves applies also to the closing. If the form of the closing part of the cam were too sudden the cam might overtake the lever, and the valve would go down on its seat with a hammer, and at a later period than that intended. The form of cam that would produce an almost ideal valve action is shown by full lines in Fig. 2. Were it practicable, this form would give nearly an instantaneous full-opening, which would be maintained until an almost instantaneous closing took place; and, if mounted on the valve-shaft of a four-stroke cycle-engine, would give an open period equal to 180 degs. of crank movement, if there were no clearance between the cam and roller and the valve-stem. The other extreme is shown by the dotted lines, the raised or active portion consisting of two tangents to a concentric or dead portion of the cam meeting in a line bisecting the total angle of the active part. The spaces enclosed between these two forms may be regarded as fields in which the active part of a practical form of cam will lie.

In the forms of cam shown by the figure, the roller arm would be stationary for three-fourths of the cam's revolution. Now, for practical reasons, there must be some clearance between the roller and the dead part of the cam, or between the roller-arm and the valve-stem; consequently the cam outline must be modified to compensate for this clearance, or the opening would be late by the angle $B\,A\,C$ in the case of the full-line cam, and by the angle

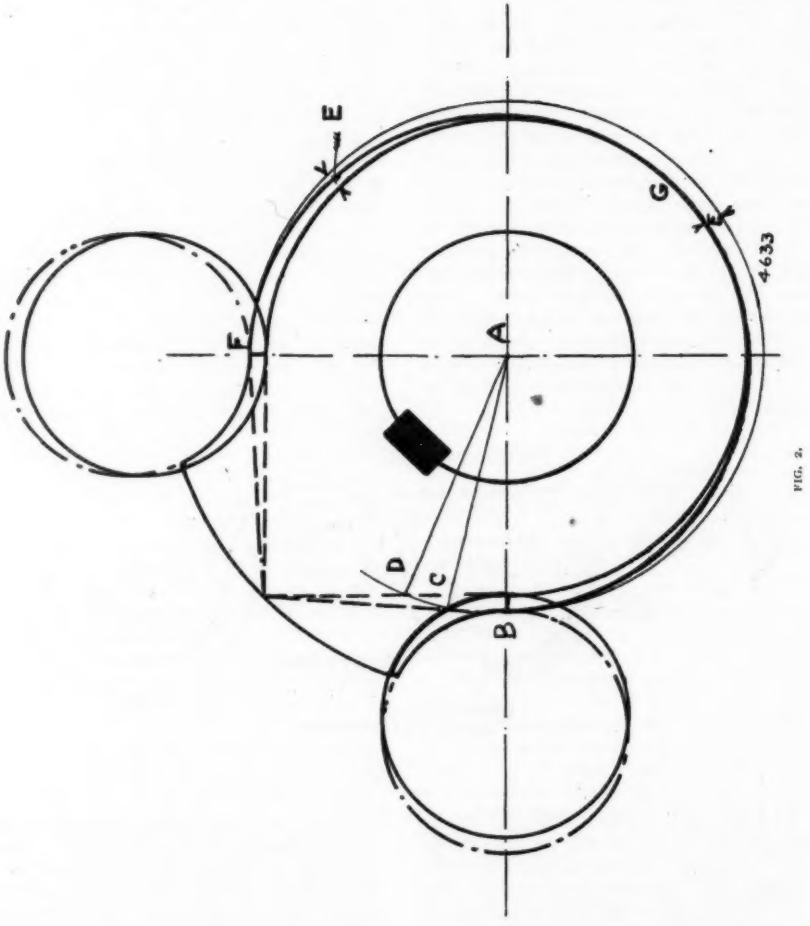


FIG. 2.

B A D in the case of the dotted-line cam, the clearance being represented by *F*. The form that would give the quietest meeting and leaving between the roller and cam, or between roller-arm and valve-stem, would be described by an arc passing through the points *F G B*. A little consideration, however, will show that such a form would not be suitable for working conditions. The slightest variation in the clearance would seriously affect the timing of the valve, and if properly timed when cold it would be out of time when the engine became hot. The other extreme is shown by the straight step, and the practical shape lies somewhere in the space enclosed between the two forms.

The next diagram, Fig. 3, illustrates the relative positions and outlines of the various cams to produce the action shown in Fig. 1. For convenience, this diagram is here reproduced above the cam diagram. The cam *A* operating the air valve

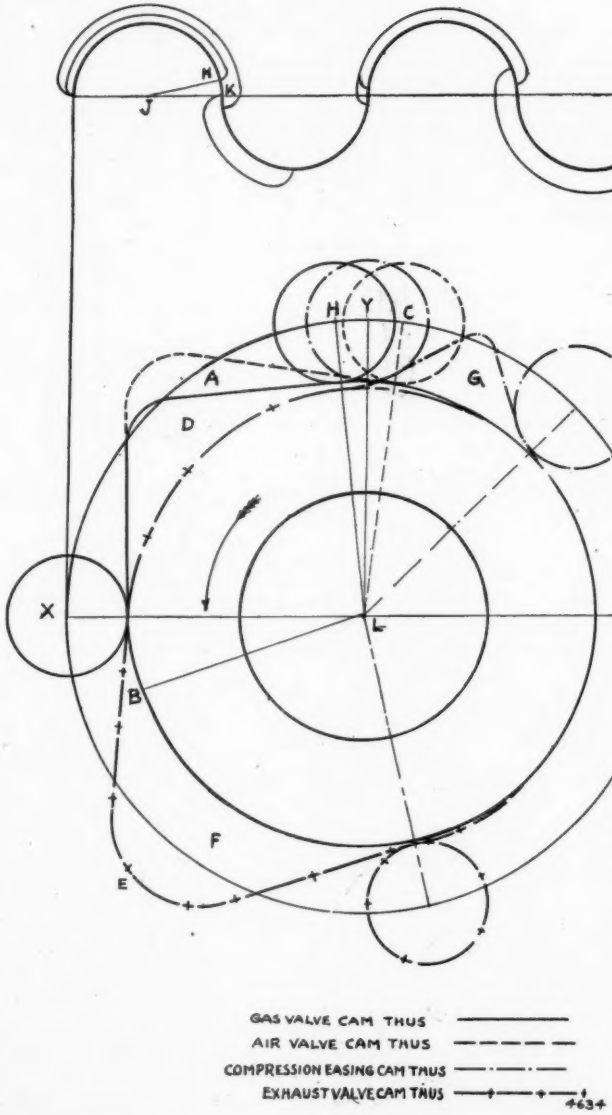


FIG. 3.

commences either to move the valve lever or work off the clearance at *B*, contact with the valve-stem occurring exactly at dead point. The valve would remain open until *C* is reached. The cams for working the other valves are shown, *D* being

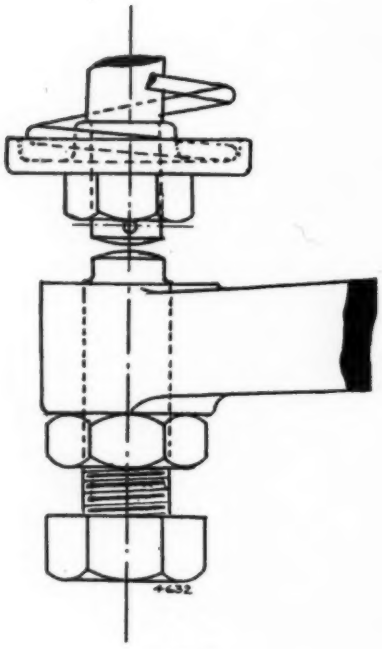


FIG. 4.

the gas cam, *E* the exhaust, and *G* the compression-easing cam. The diagram shows their relative positions, assuming that the rollers are all opposite each other when looking end-ways on the shaft. In practice this would not occur, but when their *assumed* relative positions have been determined it is an easy matter to find their *true* positions relative to each other if the positions of the rollers be known. The method of arriving at the form of the cams needs little further explanation. In each case the active or raised portion of the cam occupies half the angular distance of the valve movements on the crank-pin diagram. This condition holds in every gear on a Beau de Rochas cycle engine, whatever the position of the cams or the roller, or the forms of the arm from the cam to the valve stem. The first quadrant *XY* on the cam diagram corresponds to the suction stroke of the piston; and any point of the crank-pin diagram corresponding with any cam position is found by taking twice the angle from the starting-point of the quadrant corresponding to the particular stroke. Thus the point *H*, where the gas-valve closes, corresponds to *H* on the valve-shaft diagram, the angle *HJK* being twice the angle *HLY*. Each quadrant in the valve-cam diagram corresponds to a half-revolution of the crank-shaft or a stroke of the piston. The clearance between the roller-lever and valve-stem is usually varied by means of a set-screw and lock-nut at the valve end of the roller arm, as shown by Fig. 4. This permits accurate timing to be obtained as well as some variation in the lifting period.

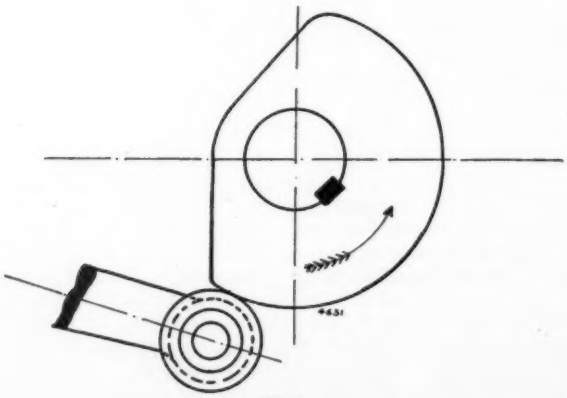


FIG. 5.

The diagram needs little further explanation. It will be noticed that the raised portion of the cams are worked into the dead or concentric parts with easy curves. The projections of the cams do not necessarily represent the actual lift of the valves, except in those cases where the valve-levers have equal arms. The ignition cams are not shown on the diagram, because their form and action differ from the

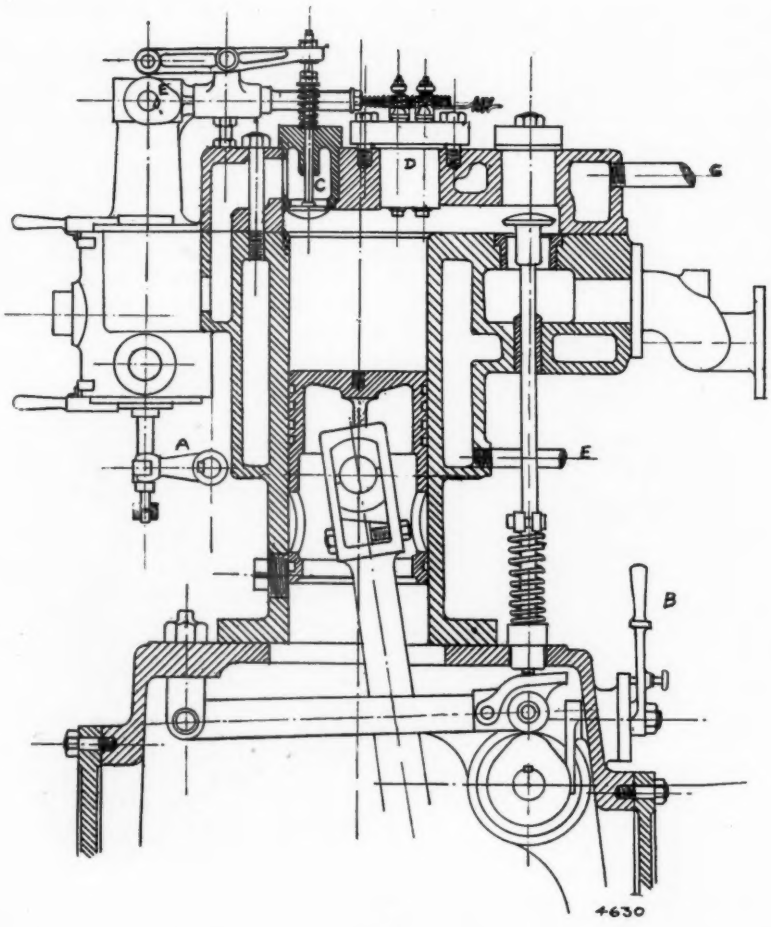


FIG. 6.

other cams considerably. It is necessary that the opening be very prompt, and as commonly arranged the pressure is beneath the valve seat, so that it must be held to its face by a spring. A form suitable for a timing valve is shown in the annexed diagram (Fig. 5), and is similar to that used by Messrs. Fielding & Platt on some of their large engines. The roller presses on the cam surface, and at the required instant the valve flies open very suddenly The rate and time of closing is not of much importance, provided that the valve is quite closed before a fresh charge begins to enter the cylinder. In the crank-pin diagram the air-valve is shown opening exactly at dead point, for the sake of convenience in drawing; but it is usual to open a little before to allow of a slight scavenging action, and also to give a better

opening for the valve on the charging stroke. The necessary alteration to the air-cam will be obvious, the raised portion embracing a slightly greater angle.

In the cams of many gas engines the refinement of a gradual working of the concentric parts into the raised portion is omitted, the straight parts being simply tangents to a concentric portion. It depends on the relative position, length and weight of the two valve-lever arms, whether the roller is in continuous contact with the cam, or whether the lifting end

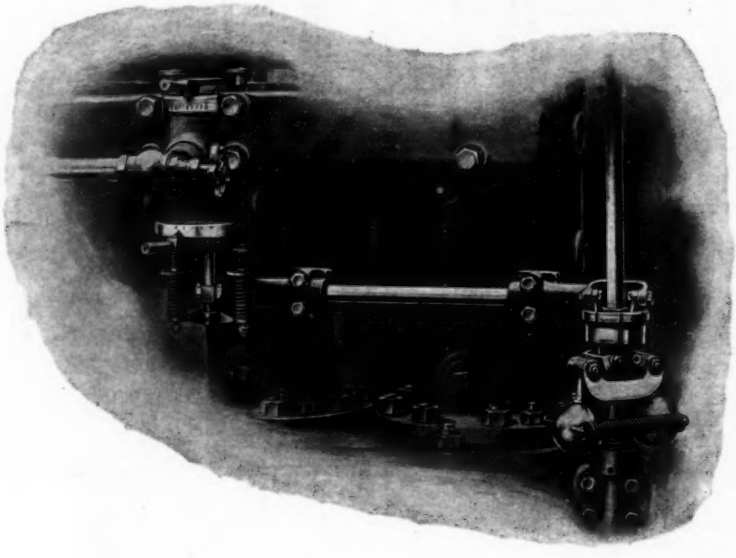


FIG. 7.

of the lever is always against the valve-spindle. In either case, unless the cams are well designed, there will be a liability to rattle at the instant the valve opens.

Where electric ignition is employed the cam or its equivalent may take many forms. Generally a spark is produced in the cylinder by breaking a circuit. As the piston approaches the end of the compression-stroke the ignitor cam brings the ignitor terminals in contact, completing a circuit. At the required instant the cam releases the terminals and they fly asunder, breaking the circuit and thus firing the mixture.

The thorough mixing of the air and gas is an important matter. In the year 1898 the writer had the privilege of making many experiments with a small gas-engine working on the Beau de Rochas cycle, and several trials were made with the object of observing the difference in running with the gases mixed in various ways: when air and gas were simply allowed to fall into the cylinder without any attempt at mixing, frequent miss-fires occurred; but when the charge was drawn through a small mixing-box containing a bundle of fine wire the speed increased and miss-fires never occurred, except the proportion of air to gas was much altered, and that suddenly. Other mixing devices were tried, such as sieves and baffle-plates, but the wire bundle gave the best results.

The importance of getting the cylinder free of the products of combustion, so that a clear charge may be drawn in, has long been recognised, and much thought has been given to the subject. In the Atkin-

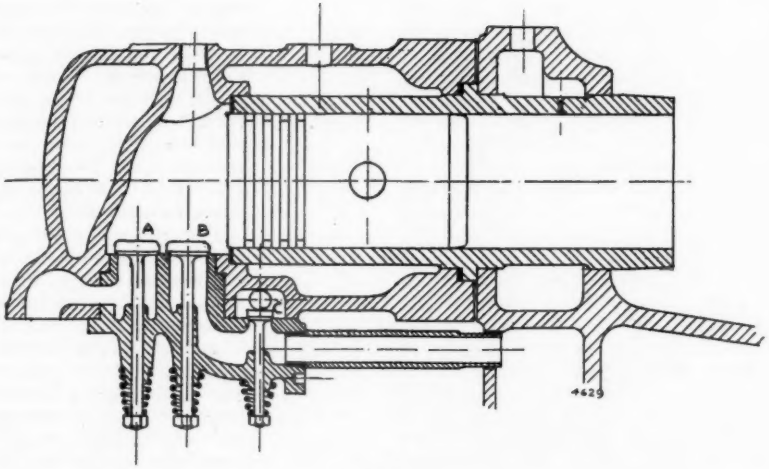


FIG. 8.

son "cycle" gas engine the clearance between the piston and the cylinder-cover on the exhaust stroke is only that necessary for mechanical reasons; but by a most ingenious arrangement of mechanism the piston makes a shorter stroke when compressing. In the "Premier" gas-engine the front side of the piston is employed to compress air to a few pounds' pressure, which, during the exhaust stroke, is admitted into the cylinder, thus effectually clearing out the exhaust products. Other engines have been designed having what is termed a scavenging stroke, and in order that the engine might not be over ponderous for the power developed, due to the fact of there being only one impulse in three revolutions, both sides of the piston are alternately subjected to an explosion, thus giving one impulse for

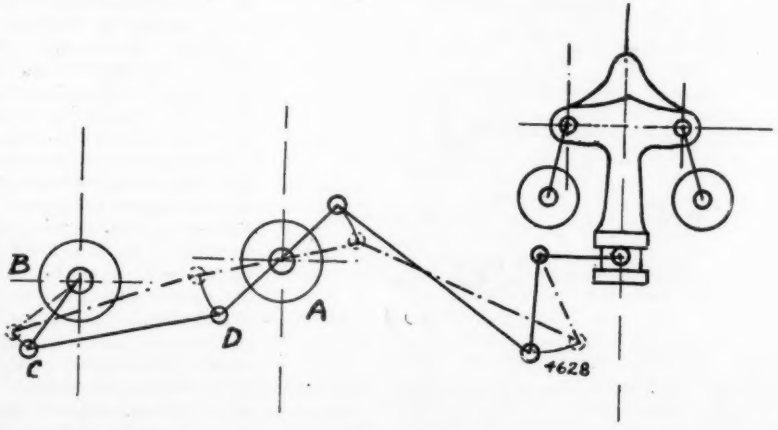


FIG. 9

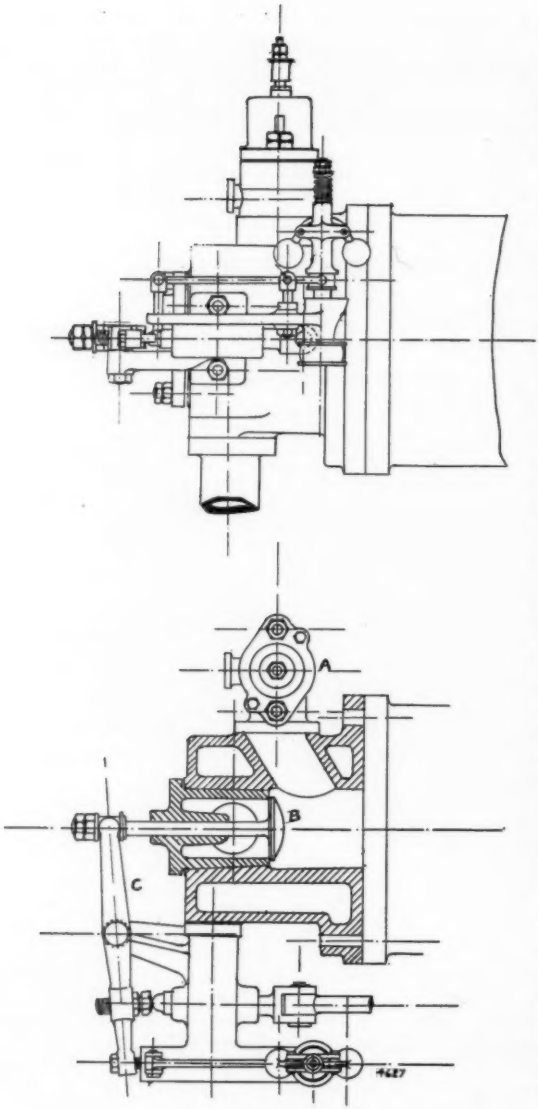


FIG. 10

every three strokes of the engine. The scavenging device of the Crossley engine consists of an exhaust pipe of a certain length, determined experimentally, in which the pulsations of the exhaust produce a slight vacuum. The air-valve in the cylinder being open, a current of pure air sweeps in and clears the cylinder. It accomplishes automatically what the "Premier" engine performs positively.

The position of the valves in the compression chamber is decided by readiness of access and convenience of operation from the cam-shaft. The large valves should be placed vertically by preference, the seating of a horizontal valve not being so certain as that of a vertical one. Each valve and seat is best made self-contained in the form of a plug in the compression-chamber; so that, by unscrewing two or more nuts, the whole may be lifted out without disturbing other parts. Other things being equal, the best results are obtained when the exhaust valve is placed in such a position that the exhaust gases sweep through any pockets in the compression-chamber, leaving no part out of the rush of the exhaust, and causing no baffling or eddies in its passage. The object to be kept in view is to design the compression-chamber with as little surface for the space enclosed as possible.

The internal arrangements and disposition of valves in several modern engines is shown by the various illustrations. Fig. 6 is a section through one of the cylinders and valve chambers of the Westinghouse engine. The position shown is that in which the exhaust valve is wide open, and the piston ascending. In general appearance these engines closely resemble a high-speed steam-engine.

They are constructed with two or three cylinders, with cranks at the same angle, or at 120 degs. to each other. In the two-cylinder engines the pistons ascend and descend together, but the setting of the cams is such that whilst the piston is making the power stroke the other is charging, and one compresses whilst the other exhausts. An impulse every revolution is thus secured in the case of the two-cylinder engines, and three impulses every two revolutions in the three-cylinder engines. The ignition is electric, the ignition cam releasing the terminals in contact, thus forming a spark in the compression chamber. One advantage of electric ignition is the absence of small ports and passages, which are necessary in a hot-tube ignitor and timing-valve arrangement. The ignition binding ports, it may be remarked, are in duplicate, as well as the current breakers. Only one set is in operation at the same time, so that the risk of total failure of the ignition tackle is greatly minimised. In series with the dynamo or other source supplying the ignition current are three incandescent lights, which serve the double purpose of modifying the strength of the current and indicating the working of the ignition apparatus.

The method of governing has already been alluded to. Referring to the figure, the lever *A* is in connection with the governor, and controls a piston throttle valve: in connection with which are two adjustable valves, regulated by levers working over graduated arcs, whereof the upper controls the gas supply and the lower one the air. The method of working is as follows: The engine being put upon a steady load, and with, say, too great a proportion of gas, the air-regulating valve is slowly opened. This increases the speed of the engine, which is seen by the descent of the regulating valve-spindle. At a certain point the spindle begins to rise, indicating that the best proportion of air to gas has been attained. The illustration (Fig. 7) shows the connection between the governor and the regulating-valve in the three-cylinder engine, as well as the handles for controlling the respective amounts of air and gas. The air inlet will be seen at right angles to the gas valve and a little below it.

The starting of these engines is accomplished by compressed air, which is stored in a small vessel specially provided. The handle *B* (Fig. 6) slides the ordinary exhaust-cam of one of the cylinders out of gear, and brings into operation a supplementary cam having two distinct raised or active portions which open the exhaust-valve on every up-stroke of the piston. At the same time a simple device throws out of gear the admission-valve of the same cylinder. In the pipe leading from the compressed-air vessel to the cylinder is a valve worked from the lower or exhaust-cam shaft, which controls the air-admission to the cylinder. The cylinder is by these changes practically converted into a compressed-air motor, and for a time impels the other piston or pistons, until regular explosions occur, when the ordinary cams are put into gear and the starting cylinder commences to operate on the Beau de Rochas cycle.

Referring again to Fig. 6, the air and gas inlet-valve is shown at *C*, *D* is the ignition-plug, and both are operated from the secondary cam-shaft *E*. *F* and *G* are the circulating water inlet and outlet respectively. The external appearance of the Westinghouse governor is shown in the next figure, which, together with the previous figure, will give a clear idea of their appearance and action.

The section of the cylinder by Messrs. Fielding & Platt is shown in Fig. 8. *A* is the exhaust-valve, *B* the inlet air-valve, and *C* the gas inlet. On the small engines made by this firm no timing-valve is provided, but the height of the ignition-tube flame is adjustable, whereby the timing of the explosion is varied. The governing is on the cut-out principle, but in large engines the makers adopt the throttling method, and in order that the reduced charges may be fired with certainty the mixture becomes richer in gas as the governor rises. This is an effect often desired in large gas engines which have to be closely governed, and is accomplished in a very simple manner by arranging the throttle valve levers at suitable angles. The diagrammatic sketch,

Fig. 9, shows a governor operating on two throttle-valves, *A* and *B*; and if the levers were arranged as shown the valve *A* would throttle to a greater degree than *B* for a given rise of the governor. By making the length of the connecting-link *C D* adjustable, considerable latitude in the movements of the two valves in relation to each other is obtainable. In the figure, lengthening the link would give less motion to the valve *B* for a given lift of governor, whilst shortening the link would have a reverse effect. Almost any combination of movements may be obtained by arranging the levers in various positions.

The Campbell engine has already been referred to as an example in which governing is effected by holding up the exhaust valve, and Fig. 10 shows the details of this arrangement. The inlet-valve is shown at *A*, and is automatic in its action. The exhaust-valve *B* is worked from an eccentric on a counter-shaft geared to half the speed of the crank-shaft, and at about 93 per cent. in the power-stroke, the end of the slider strikes the exhaust-lever *C*, the set screw permitting of some adjustment in the time of contact. The governor operates by interposing a stop between the end of *C* and a fixed part of the carrier-bracket, and thus prevents the exhaust-valve from seating. In this state of things the piston simply draws air up the exhaust-pipe and returns it on the back stroke down the same passage, the inlet-valve being then entirely inoperative. In the latest type of engine Messrs. Campbell have abandoned this arrangement in favour of the ordinary four-valve type of engine. Whether the recent advances in gas-engine construction have absorbed most of the progress that is possible time alone will discover, but there seems every probability of great improvement. Compounding at one time seemed to open up a great field of improvement, but there is always this difficulty—that the high-pressure cylinder must be cleared for each new charge if anything like perfect combustion is to take place. The exhaust from the gas engine is of great temperature but of inconsiderable pressure, and the problem is to convert this temperature into work. It would be a worthy task for some wealthy investigator to inquire whether some of the heat from this exhaust could be imparted to the hot water in the jacket, in order to generate a gas for use in other cylinders. The difficulties to be encountered would doubtless be numerous, but even failure would evolve valuable information and have its compensations.

When it is remembered that in average cases 30 per cent. of the heat in the gases is lost in the water-jacket, and 47 per cent. in the exhaust and by radiation, there certainly appears great scope for advancement. As to the mechanical details of gas engines, they are being rapidly improved. With the increase of compression, water-cooled exhaust-valves and pistons have been found necessary, whilst the bed plates have been strengthened up enormously, and so designed that the section of the metal is more evenly distributed round the axis of the piston, thereby lessening the tendency to spring in the frame at the instant of explosion. The use of low-valve power gas has given a great impetus to the manufacture of large engines; and the construction of engines of 1,500-h.p. presents no insurmountable difficulties, and is, indeed, quite within the practice of several makers.

Entropy.

A Review of the Controversy, Swinburne *v.* Perry: Lodge intervening.

We have no doubt many of our readers have followed closely the controversy which has for the past two months been waging in the weekly technical journals over the correct definition of that troublesome function called entropy. All was peace until Mr. Swinburne, in his presidential address to the Institution of Electrical Engineers, suddenly and in characteristic fashion launched a thunderbolt against "pedagogues" and writers of text-books on engineering and mathematical physics, by boldly accusing them of giving a wrong definition of entropy. It was not surprising that this should provoke a reply from one of the persons attacked, nor that the one to take up the cudgels should be Professor Perry; but it is certainly much to be regretted that, in his first contribution, that gentleman should have shown so much personal feeling. Had Mr. Perry been blessed with a greater sense of humour, we feel sure he would have adopted a different line of attack. Right or wrong, Mr. Swinburne is sincere in his opinions and straightforward in the expression of them; and, as he was careful to point out at the beginning of his address that all his statements—other than those of accepted facts—must be read as his opinions and nothing more, it is difficult to see why an opponent, even if he be angry and contemptuous of these opinions, should condescend to personalities. However, the controversy in its later stages has become milder in tone and therefore more instructive. Mr. Perry sent copies of his letter to all the leading weekly journals devoted to engineering and electricity, and the consequence is that since then contributions to the discussion have appeared more or less regularly in all these papers. There is therefore plenty to read for anyone who desires to go through the whole matter, and indeed it is necessary to refer to the different journals to get a complete statement of the views of the opposing parties. The principal "third party" to the discussion is Sir Oliver Lodge, who, by request, sent a short article on Entropy to the *Electrician*, in which he endeavours to clear the ground somewhat of some ambiguities. At the time of writing, the discussion is not yet closed, but it may be useful if we give here a short summary of the situation, explaining to our readers the exact differences between the views of Mr. Swinburne and those of the text-book writers whom he has criticised.

The origin of the controversy is found in Note C to Mr. Swinburne's address, which begins with the statement that there is an unfortunate misconception as to the nature of the function entropy in most treatises on the steam and gas engine, and contains near the end the following sentence:—

> "It may be urged that the definition of Entropy, with which I find fault, is given not only in engineering text-books, but that it occurs in nine out of ten treatises on mathematical physics. That is so; most writers define entropy incorrectly."

It may be well, then, before considering Mr. Swinburne's views, to set out the definition of the text-books to which he objects. Professor Perry evidently considered that he was one of the writers attacked, and in his later contributions Mr. Swinburne has stated quite plainly that this is the case, so we turn to Professor Perry's book on *The Steam Engine*, and at p. 314 we find the following statement:—

> "If stuff is at the absolute temperature t, and we give the small amount of heat δH to it, we say that we give it the Entropy $\delta H/t$. Engineers seem to have great difficulty in understanding why we introduce the notion of this ghostly quantity, but they must get accustomed to it. . . . . It is a mathematical idea which must be taken in, and it is almost impossible to get the idea without working exercises on heat engines."

We are afraid our readers may not consider this a very explicit definition, or

one likely to give them a clear conception of what is meant by entropy. Indeed it in fact says that one must not expect to have a clear notion of the meaning until he has worked exercises on heat-engines, when he will find the "mathematical idea" extremely useful. We have as yet, however, disclosed Professor Perry's position only partially. We have omitted from our quotation a sentence of some importance, simply because in a contribution to the present controversy Mr. Perry has expressed its substance in a more concise form, which we now set out:—

"dH is the heat entering a quantity of stuff which is at the absolute temperature θ, and pressure p, and volume v. If dH/θ be called $d\phi$, then ϕ is a property of the stuff which returns to its old value when θ and p and v return to their old values after any changes. This is the second law of thermodynamics."

Let us deal briefly with this statement. The first point to notice is that, with Mr. Perry, ϕ, or entropy, is *a property of the stuff*. The absolute value of the entropy at any moment we do not know; it is only changes of entropy with which we are concerned, and we may take any arbitrary state as that of zero entropy. If heat dH_1 is given out at temperature θ_1, the entropy is dH_1/θ_1, so that the change of entropy is

$$\frac{dH}{\theta} - \frac{dH_1}{\theta_1}.$$

If, however, the quantities of heat received or removed are continuously changing, and the temperatures also, then the change of entropy is obtained by summing up all the infinitely small changes, that is, counting from the state of zero entropy,

$$\phi = \int \frac{dH}{\theta}$$

This, then, is an equation following at once from Mr. Perry's statements, and giving an expression for the entropy. Notice that in what we have quoted from Mr. Perry's writings, we find no qualification concerning the reversibility or otherwise of the operations.

We shall return later to the concluding sentence of our quotation—"This is the second law of thermodynamics"—but let us now see what Mr. Swinburne has to say concerning the definition expressed in the mathematical equation above. In Note C to his address, we find the following:—

"Though it is numerically correct in the limiting and purely hypothetical case of reversibility, the equation

$$\int \frac{dH}{\theta} = \phi$$

as a definition of entropy is fundamentally wrong. It gives a wholly wrong notion of entropy."

This statement is enlarged by Mr. Swinburne in his reply to Mr. Perry (*Electrician*, Jan. 2, 1903). He says:—

"They [*i.e.* the text-book writers] are wrong essentially in defining entropy, ϕ, as

$$\phi = \int \frac{dH}{\theta}$$

because ϕ is only numerically equal to $\int dH/\theta$ in the limiting case of reversibility, and is in nature always greater than $\int dH/\theta$. The excess of ϕ over $\int dH/\theta$ was called by Clausius the 'uncompensated entropy,' and no process in creation can go on without the production of uncompensated entropy, or without increasing the entropy of the universe."

The contributions to this controversy from both sides have occupied columns and columns of the principal weekly electrical and engineering journals, but this paragraph just quoted from Mr. Swinburne and our last quotation from Mr. Perry express the whole difference between these two writers. Compare the two paragraphs, and it will be seen that the difference is twofold: (1) Mr. Perry gives a definition of entropy which Mr. Swinburne says is only true in the imaginary case of wholly reversible operations. In such a case,

$$\int \frac{dH}{\theta} = \phi;$$

but such a case never occurs in nature, and the definition is wholly incorrect when applied to real changes. In all real changes

$$\phi = \int \frac{dH}{\theta} + \text{uncompensated entropy.}$$

(2) Mr. Perry calls entropy "a property of the stuff," and deals only with the change of entropy in this one particular substance or stuff under examination. Mr. Swinburne, on the other hand, treats entropy apart from the "stuff" in which at any moment it may be found. He follows

entropy from one body to another, and speaks of "the entropy of the universe" in the same way as we speak of the energy of the universe. To him the entropy is the real thing, and the state of the working stuff is only of minor importance.

Here, then, we have an explanation of the controversy, and it appears that these two gentlemen are really quarrelling over different things denoted by the same name! Something has been gained, however, by this disclosure that entropy can mean different things to different people, for it has led to an examination of the definitions, and to the discovery that some writers have not been as exact as they might have been. The credit of this discovery is due to Mr. Swinburne; for it proves to be true, as he alleged, that many writers have dealt only with reversible processes, and have failed to indicate how their definition must be qualified or corrected to be applicable to real—*i.e.* non-reversible—changes. These writers, no doubt, are fully aware of the limited truth of their statements, but it is due to their readers, who are seeking information with a view to applying it to real processes, to put them on their guard against accepting the purely hypothetical for the real.

The second distinction above between the views of Mr. Swinburne and those of Mr. Perry is worthy of careful attention. It comes to be largely a matter of definition, it is true, but it is our aim to find which definition is the more accurate and the more useful. Consider a heat-engine with a working substance—Mr. Perry's "stuff"—taking in heat H_1 at (absolute) temperature θ_1 and giving out heat H_2 at temperature θ_2. Then the change of entropy is

$$\frac{H_1}{\theta_1} - \frac{H_2}{\theta_2};$$

and if the stuff be going through a (hypothetical) reversible cycle,

$$\frac{H_2}{\theta_2} = \frac{H_1}{\theta_1},$$

so that there is no change of entropy. That is, taking the case of continuous variation of H and θ,

$$\int \frac{dH}{\theta} = 0.$$

Now θ_1 and θ_2 here are the temperatures *of the stuff* when heat is taken in and removed, and only in a reversible cycle are these the same as the temperatures of the source and condenser. The temperature of the source is always higher than the temperature of the stuff to which it supplies heat, while that of the condenser is always lower than the temperature of exhaust, so that

$$\frac{H_1}{\theta_s} < \frac{H_1}{\theta_1}$$

and

$$\frac{H_2}{\theta_c} > \frac{H_2}{\theta_2},$$

denoting by θ_s and θ_c the temperatures of source and condenser. We therefore have

$$\left(\frac{H_2}{\theta_c} - \frac{H_1}{\theta_s}\right) > \left(\frac{H_2}{\theta_2} - \frac{H_1}{\theta_1}\right),$$

so that there is a larger increase of entropy than in the case where we consider only the working substance and its temperatures, and if we brought back everything to its original condition, we should not have $\int dH/\theta = 0$. Of the two meanings given to entropy, then, Mr. Swinburne's can be practically applied to real changes, and can be adapted to the special case of reversibility. Mr. Perry's, on the other hand, is not applicable to real changes, but only useful as a mathematical idea, to be applied in heat-engine diagrams. Clausius, who is responsible for the word entropy, used the term for both reversible and non-reversible changes, but he was very careful to point out the strict limitation of the equation $\int dH/\theta = 0$ to reversible changes. In his work on the "Mechanical Theory of Heat," he points out that transference of heat from a source to the working substance presupposes a difference of temperature, so that the heat is never taken in at the same temperature as that of the source, but that, in a reversible process, we can consider the difference to be so small that the two are practically at the same temperature. He then proceeds:—

"If, however, we . . . . suppose that in forming equation VII. [$\int dQ/\theta = 0$] every element of heat Q is taken of that temperature which the

variable body possesses at the moment it is taken in, then we can now ascribe to the heat reservoirs any other temperatures we please without thereby making any alteration in the expression $\int dQ/\theta$. *With this assumption as to the temperature*, we may consider equation VII. as holding, without troubling ourselves as to whence the heat comes which the variable body takes in, or where that goes which it gives off, *provided the process is on the whole a reversible one.*

"The expression dQ/θ, *if it be understood in the sense just given*, is the differential of a quantity which depends on the condition of the body, and at the same time is fully determined as soon as the condition of the body at the moment is known, without our needing to know the path by which the body has arrived at that condition; *for it is only in this case that the integral will always become equal to zero* as often as the body, after any given variations, returns to its original condition. In another paper . . . . the author proposed to call this quantity after the Greek word τροπή, transformation, the entropy of the body."—[*Translation by W. R. Browne* (1879), p. 106.]

This is all quite clear, and there is no possibility of confusing the special circumstances relating to reversible processes with those of the general case in nature, for, in the words we have italicised, Clausius emphasises again and again the very special character of a reversible cycle. Practically, the main use of the reversible cycle is that it enables us to give a mathematical expression for the *numerical value* of the entropy, and this has led writers to ignore the true character of entropy in real non-reversible changes. They have adopted the statement which Clausius made, that "the sum of all transformations in a cyclic process must be zero," but they have not pointed out clearly how he modified that statement when he desired to make it cover both reversible and non-reversible changes. His general principle is stated thus:—

"The algebraic sum of all the transformations which occur in a cyclical process must always be positive, or in the limit equal to zero."

Or, otherwise expressed, "Uncompensated transformations must always be positive."

The danger of holding too closely to mathematical conceptions is well exemplified by our quotation from Professor Perry, in which, after expressing in words the fact that round a reversible cycle $\int dH/\theta = 0$, he adds, "This is the second law of thermodynamics." It is nothing of the kind. It is, in fact, only a mathematical representation of the second law in a very special case; but that law, as laid down by Kelvin and Clausius, was quite general. Why should Mr. Perry seek to constrain it to a special case? And why should he state the special case inaccurately by failing to make any mention of the essential reversibility of his cycle? We may as well give the second law, as expressed by its authors, so that readers may compare it with the mathematical representation above.

Clausius: "It is impossible for a self-acting machine, unaided by any external agency, to convey heat from one body to another at a higher temperature; or heat cannot of itself (*i.e.* without compensation) pass from a colder to a warmer body."

Kelvin: "It is impossible by means of inanimate material agency to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of surrounding objects."

These expressions are perfectly general, and apply to all engines working in complete cycles, whether reversible or non-reversible; and they are, in our opinion, much more useful to the student than the mathematical equation whose meaning may be missed altogether.

So far, then, we are led to the conclusion that Mr. Swinburne is justified in his criticisms of the ordinary text-book definition of entropy, certainly, at least, as regards Mr. Perry. We have not had an opportunity of examining more than a few text-books, but it is somewhat curious that in the first one to which we turned after reading the controversy, we found the whole matter stated quite simply and clearly, and free from ambiguity. This book was our old friend, Preston's "Theory of Heat," and our admiration for the work of the late Professor Preston was confirmed when we found how he has avoided the error into which so many other writers have fallen. We hope Mr. Swinburne will not include this work in his "black-list" of nine-tenths of the text-books on physics.* Professor Preston does not go quite so far as Mr. Swinburne does in some respects, but he distinguishes between reversible and real processes,

* It may be that, as this is a book on Heat, Mr. Swinburne would not include it among text-books on Physics, but among those on Thermodynamics, with which, as he has stated, he has no great fault to find.

and he discusses entropy both in connection with a single body going through a cycle and with regard to a whole system of bodies, or even the whole universe. We have not found the same treatment in any other text-book to which we have been able to refer, but Sir Oliver Lodge, in his contribution to the *Electrician*, points out how it is possible to consider entropy from these two points of view. He, however, obviously considers that the only proper view is to regard it in its relation to the working substance—to consider only temperatures of that body, and to have no regard for temperatures of source and condenser, except in so far as we try to make the range of temperature of the working substance as nearly as possible equal to that between the reservoirs. He thus to some extent shares Professor Perry's view, but he recognises the possibility of another view, of which he does not approve, being taken. Mr. Swinburne, as we have seen, considers very strongly that that other view is the only correct one. "Entropy," he says, "is a function that essentially concerns the reservoirs"; every real change is accompanied by an increase in the total entropy of the *system* of bodies affected by the change. One body may lose entropy, but another gains more than the first has lost. "The real point is the fact that no change in the universe can take place unless it increases entropy, and that this is . . . . a law of Nature which ranks in importance with that of gravitation."

Here Mr. Swinburne appears to carry his view to an extreme, for although a consequence of every natural change is that the entropy of the universe is thereby increased, it does not seem necessary on that account to raise this into a law on the same level with that of gravitation. In the first place entropy is too fanciful, too "ghostly" a thing to be readily grasped, and men are not likely, when seeking to find whether a particular action will take place or not, to ask themselves, "Would the entropy be thereby increased or diminished? If the former, the action will take place; if the latter, it cannot." Looked at in one light, Mr. Swinburne's law of the increase of the entropy of the universe is closely akin to the much more familiar law of the dissipation of energy. To say that the entropy of the universe is increasing is, in a certain sense, another way of saying that the energy of the universe, although constant in amount, is gradually becoming less available for conversion into mechanical work. For if a system undergoes a change, with a consequent increase of entropy, we cannot restore the system to its original state without degrading work into heat, so that some of the energy of the universe is dissipated. Thus the two laws are identical if we are considering closed cycles; but Mr. Swinburne's position would be that the degradation of energy cannot be taken as the criterion whether or not a change will take place, and that the only criterion in some cases—*e.g.* chemical changes—is the one given above, the increase of entropy. Of course, if we adopt the view of Professors Perry and Lodge that increase of entropy only occurs by the transfer of heat *as heat*, then, as heat always passes from a higher to a lower temperature, its motivity is reduced by the change, and we have increase of entropy necessarily accompanied by loss of availability, or dissipation of energy. But Mr. Swinburne denies the correctness of that view.

Since the above remarks were written, striking support has been given to Mr. Swinburne by Professor Planck of Berlin and Professor Poincaré of Paris, who have sent communications to the *Electrician*. We must be content at present merely to refer to these communications, as all we have set ourselves to do here is to provide our readers with a review of the whole discussion, and to indicate the points of difference between Mr. Swinburne and his critics. We understand that Mr. Swinburne intends to expound his views at greater length in a paper which he is now preparing, and our summary of the controversy may be a useful preparation for the study of that paper. It may also help to a better appreciation of the original contributions to a discussion which, in spite of some regrettable features, deserves to be closely studied, and ought to be productive of good.

Manufacturing Section

Some Recent Tools.

THE 8½-in. patent self-acting sliding, surfacing and screw-cutting lathe forming the subject of the first illustration has been designed by Messrs. Ward, Haggas & Smith, of Keighley, to use the high-speed cutting steels now obtainable. It embodies many improvements made necessary by the new conditions which these steels have created, and nothing has been allowed to stand in the way of handiness, stiffness, and durability.

The headstock is of heavy and rigid design, provided with four-speed cone pulley of large diameter, having powerful double-purchase gearing; the spindle speeds are arranged in correct geometrical progression, from the highest to the slowest. The larger size machines are supplied with two rates of double gearing on the back socket, which are not shown on the illustration.

The spindles are of forged steel, running in gun-metal bearings of large diameter, the front being provided with an automatic oil-feeding arrangement, which keeps it cool under the heaviest cuts. The feed-reversing gear is situated on the headstock, and is of an improved design, allowing the screw-cutting gear to be driven either at the same speed or four or eight times as fast as the main spindle, according to the size of lathe. This arrangement is found to be a great convenience in cutting quick-pitch screws, and screws of, say, 4-in. pitch, are cut with no more strain being put on the change-wheels and other screw-cutting gears than occurs when cutting in an ordinary lathe ½-in. pitch.

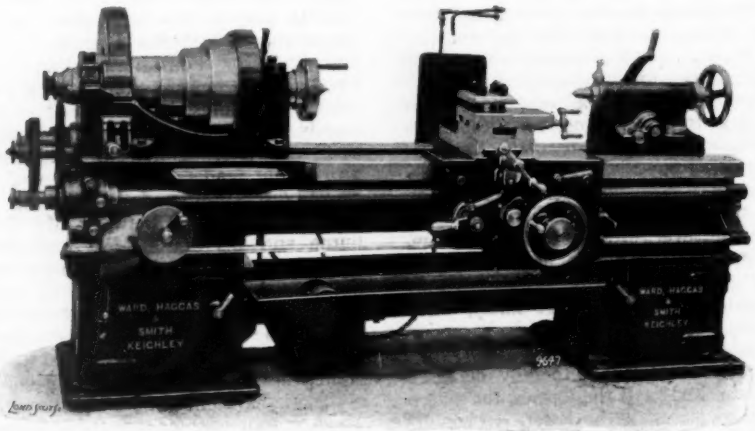


FIG. 1.—8½-IN. SELF-ACTING SLIDING, SURFACING AND SCREW-CUTTING LATHE.

The bed is of a box section, which has been patented by the makers, and is held to be much stiffer than the girder section formerly used. It is of ample depth and width across the slide face, which has a narrow guide strip on the front edge, thus securing for the saddle a long and narrow guide surface. This arrangement gives a very smooth and free motion of the saddle, and does away with any tendency towards cross-binding. The bed is supported on cabinet feet, one of which is fitted with a rack for change-wheels, the other with shelves for tools; and troughs are also formed on the feet, which conduct the suds to a trough provided with a cistern and strainer, and a positive sud pump, which is suspended between them.

The loose head is of an exceptionally rigid construction, having a sliding steel spindle of large diameter. It is provided with a transverse adjustment for taper turning, and is clamped in any desired position by means of a locking handle. It is firmly secured to the bed by a strong eccentric in the case of machines of small size, and by bolts in the case of larger sizes, and is provided with oil-well and pin for lubricating the dead centre. The head is so designed, in conjunction with the bed, that it is always drawn firmly against the back square cage of the lathe, which is subject to no other wear. This secures permanency of alignment with the fast headstock.

The saddle is so arranged that the cutting pressure is always well within the slide surface; this feature, together with the great solidity of the saddle and slides, secures steadiness under the heaviest cuts. The saddle has ample seating surfaces, and the guiding edges, upon which the truth and accuracy of the lathe depend, are so placed that it is practically impossible for dirt to lodge upon them.

The feeds are operated either by a friction-cone clutch or a lever, both of which are conveniently placed on the apron. The clamp nut for screw-cutting is operated by a lever, which also effects a quick withdrawal of the tool slide. The saddle and surfacing slides have each three rates of feed in the small sizes, and six in the larger ones, the change being effected by a conveniently-situated lever and dial near the fast headstock, which can be easily and safely operated whilst the lathe is running. All wheels are cut from the solid, and all pinions subject to heavy duty are of forged steel. Neat and secure guards are provided over all running gears.

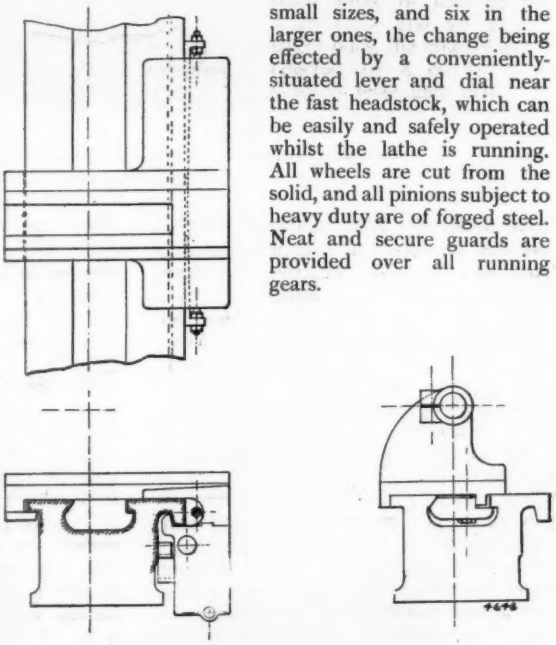


FIG. 2.—DETAILS OF BED, SADDLE, AND LOOSE HEAD.

Fig. 2 shows a section of the bed of this machine with the saddle and loose head upon it.

The other illustrations are machines recently turned out by Messrs. James Spencer & Co., of Hollinwood, Fig. 3 being a double cylinder-boring machine capable of boring two cylinders simultaneously, one bar taking from 4-in. to 8-in. diameter cylinders, and the other

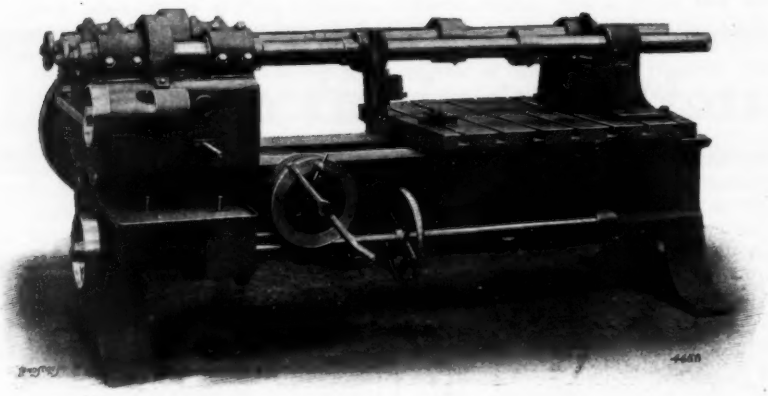


FIG. 3.—DOUBLE-CYLINDER BORING MACHINE, SPECIALLY ADAPTED FOR HIGH-SPEED CUTTING AND COARSE FEEDS.

from 6½-in. to 12-in. diameters. The distance between the bars is adjustable from 7-in. to 15-in. centres, and both bars will fit either of the spindles.

The bed is 8 ft. long, mounted on standards, and fitted with a table 3 ft. 6 ins. long by 2 ft. 9 ins. wide, having planed T slots on top surface, the table being actuated along the bed through a traverse of 2 ft. 6 ins. by a steel screw worked with variable feeds, a quick hand motion being also provided. The driving headstock is fitted with two steel spindles running in parallel capped gun-metal bearings, and each spindle is driven by a gun-metal worm-wheel working into a worm running in oil, the worm shafts being coupled by a pair of spur wheels and driven by a three-speed cone pulley.

Each spindle is carried by a transverse slide, having an independent screw adjustment to vary the centres of the spindles from 7 ins. to 15 ins. apart. The front ends of spindles are bored up for driving boring bars, etc., and an outer bracket to fix on the table is provided for supporting the outer ends of long boring bars.

The machine illustrated in Fig. 4 is a special 9-in. centre double-geared self-acting sliding and surfacing lathe, on straight bed, 11 ft. 6 ins. long, to admit 7 ft. between the centres, and having the fast headstock cast in one with the bed, driven by three-speed cone pulley—each speed 3⅜ ins. wide, largest 15 ins. diameter, smallest 9½ ins. diameter—and two sets of back gear. The double gear is 13·6 to 1, and the intermediate is 3·8 to 1. The gear wheels throughout have machine-cut teeth.

The fast headstock is fitted with a steel spindle, 4½ ins. diameter by 6 ins. long in front neck, and runs in parallel gun-metal bearings, the loose headstock being fitted with a steel spindle and split binding arrangement.

The bed is 18¾ ins. wide across the top surface, by 12¼ ins. deep, and is fitted with a strong self-acting saddle, arranged for sliding by means of a steel guide-screw carried inside the bed under the front face. The self-acting surfacing motion is worked from a shaft running along the front of the bed, driven by gearing at the fast headstock end.

Suitable gearing is provided to give four variations of speed, which can be instantly changed by means of a lever for both sliding and surfacing motions. This gearing is carried between the supports at fast headstock end, and is completely enclosed by cast-iron guards at back and front of lathe. The traverses for sliding are 32, 16, 8, and 4 per inch respectively, and those for surfacing are 56, 28, 14 and 7 per inch.

The saddle is fitted with compound slide-rest without swivel, and has quick hand traverse by rack and pinion. Drip pans, supported between the standards, are provided to catch the soap-water or other lubricant used.

The last illustration, Fig. 5, is that of an improved electrically-driven lathe for boring and turning cast-iron pipes up to 2 ft. 6 ins. internal diameter and 12 ft. 6 ins. long, and was constructed by Mr. George Addy, of Sheffield. The bed is of semi-box section, of very strong and substantial proportions, upon which are fitted two headstocks having spindles of very large diameter running in gun-metal bushes. To these spindles the face plates are secured, each of the latter being arranged to carry a suitable cutter-ring fitted with cutters—one for internal cutting and one for external cutting. Each headstock has a self-acting variable feed motion, which can be instantly put in or out of gear by the large levers situated behind the star-wheels, the method of altering the rate of feed being by moving the top lever on the gear-boxes either up or down. The headstocks are also moved by hand by the star-wheels.

The driving is effected by two electric motors, which are independent of each other, and are provided with starting double-pole, and regulating switches. Six speeds can be obtained on the spindles by the gearing and three by the 25 per cent. regulation on the switches. The speed of the spindles is altered by moving the bottom lever on the gear-boxes to the right or left, and also by adjusting the regulating switches. The cradles for holding the pipes are of a new and improved type, and are adjustable for taking large or small pipes. The cramp works on a pillar, and can be swivelled to the back of the lathe when putting in a pipe or in taking one out. It can be brought back instantly to the required position and screwed down. The lathe, the total weight of which is $15\frac{3}{4}$ tons, is also fitted with an arrangement for belt-driving.

A Novel Pelton Wheel Installation.

THE illustrations on page 255 show the details of a Pelton Wheel installed by Mr. P. Pitman, of Halifax, at the residence of Sir Richard Wyatt, Dolgelly.

The wheel is supplied with water from two separate reservoirs, the pressure from each being approximately 60 lbs. and 90 lbs. per square inch respectively. The wheel, which is of the disc form, without

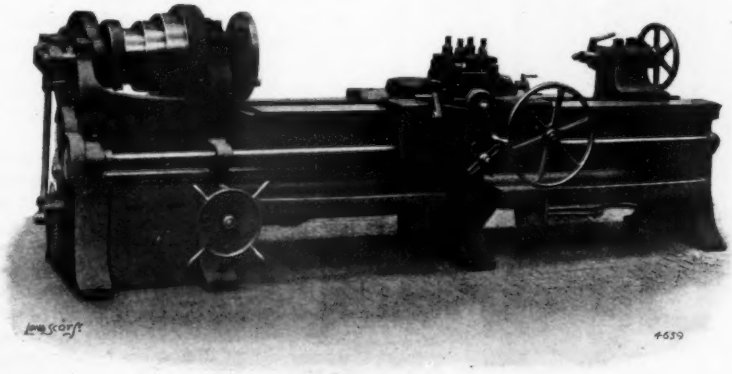


FIG. 4.—9-IN. SLIDING AND SURFACING LATHE.

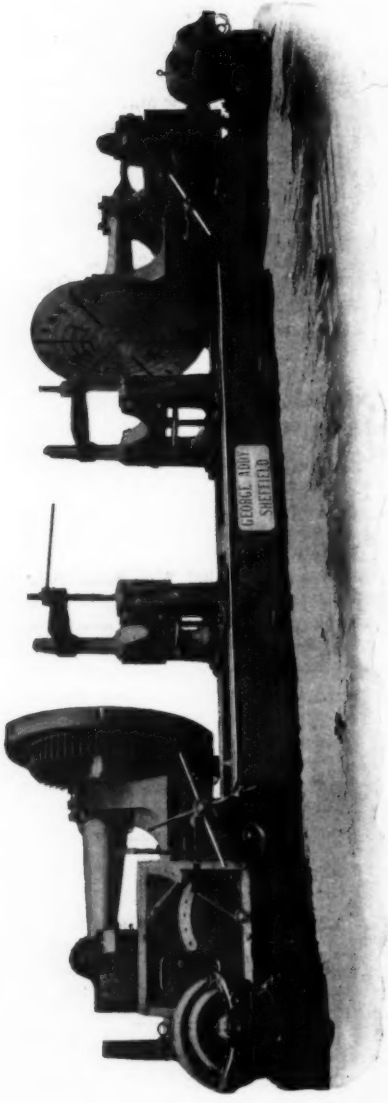


FIG. 5.—ELECTRICALLY DRIVEN IMPROVED LATHE FOR BORING AND TURNING CAST-IRON PIPES.

arms, has a diameter of 3 ft., and the buckets, which are made of phosphor-bronze, are fixed to the rim. A feature of interest attaches to the design of the buckets, each one being so arranged as to throw the deflected water quite clear of the wheel and the succeeding buckets. As will be seen from Fig. 2 they are widened out at the sides to allow the water to spread as its velocity diminishes.

The turbine wheel is contained in a boiler-plate case or splash guard, which is in turn firmly bolted to an oak framing, to which the bearings are also fastened.

The two nozzles, T and T^1 (Fig. 1) can be quickly removed without breaking any pipe joints, permitting others of a larger or smaller bore to be inserted. By this means a large range of power is obtained. Each nozzle can be further regulated by a full way valve as shown ; and these are shut off when changing nozzles or when it is necessary to stop the motor.

The upper water supply through D has the lower pressure of 60 lbs. per square inch, which develops with the largest nozzle 4 b.h.p. The lower water supply entering through E is at the higher pressure of 90 lbs. per square inch, and with the largest nozzle develops 6 b.h.p. In combination the power is 10 b.h.p.

Both connections for the nozzle are firmly fixed to the case, and both valves, by coming quite clear of the timber frame-work, are easy to operate.

Fig. 2 shows a plan and section of the new form of bucket.

The "Ward-Leonard" System of Electrically Operating Printing Machinery

at the Offices of Messrs. Edward Lloyd, Ltd.

THE "Ward-Leonard" system of operating printing machinery, though somewhat extensively used in the United States, has been introduced, for the first time in this country, for working one of the large machines in the offices of Messrs. Edward Lloyd, Ltd., where it

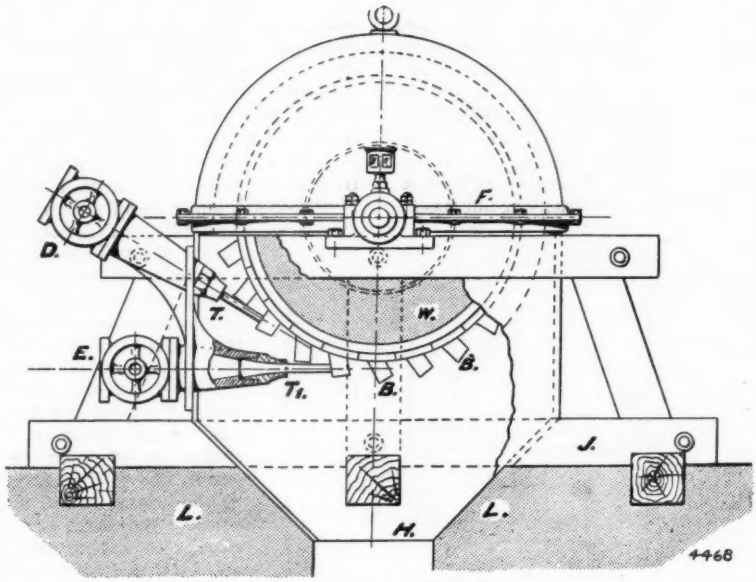


FIG. 1.—IMPROVED PELTON WHEEL.

has been operating a 50-h.p. Sextuple Hoe Press for some 18 months of regular practical work.

Generally speaking, the "Ward-Leonard" system of controlling motors consists in delivering the electricity to the press motor at a variable voltage, suited to the precise speed at which the motor is running from time to time. For this purpose it is necessary to have a generator with a rheostat in the field thereof, for so varying the voltage. This generator may be driven by another motor, or by some external source, while it may generate the whole of the electrical power required, or, as in the case of Messrs. Edward Lloyd, Ltd., only one-half thereof. Here the generator is only half the size of the press motor, and it is driven by another motor, which is also about half the size.

The arrangement is shown in Fig. 1, where *A B* is a motor generator, of which *A* is the motor and *B* is the generator, good for 25-h.p.; the armatures of both are wound for 200 volts. *E* is the press

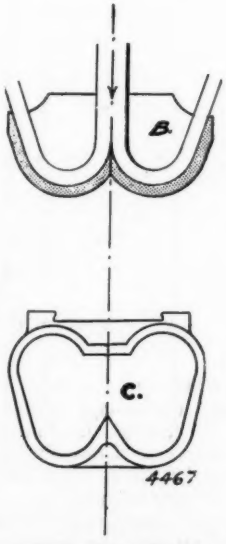


FIG. 2.—IMPROVED PELTON WHEEL: DETAILS OF BUCKETS.

motor, good for 50 h.p., the armature of which is wound for 400 volts. *C* and *F* are the fields of the generator and press motor respectively. Both of these fields are separately excited, and *C* has a reversible rheostat in circuit with it, having a large number of contacts. It will be seen that the current supplied from the line to the armature of *E* passes through the armature of *B*, which runs continually at full speed.

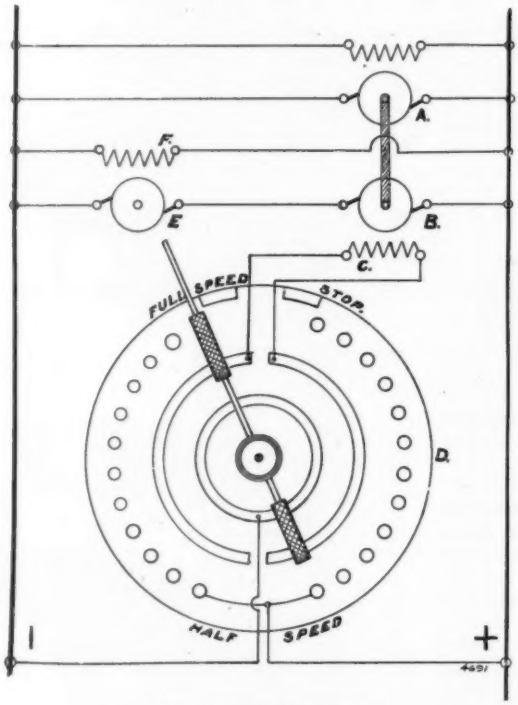


FIG. 1.—DIAGRAM OF CONNECTIONS.

When starting up, the field *C* is fully excited, and the voltage of the armature is equal to that of the line, but in a counter direction. Consequently, no current passes through *E*. The switch of the rheostat is now moved in a clockwise direction, and a small resistance is inserted in field *C*, so that the armature voltage is slightly reduced below that of the line. A current sufficient for the full torque then passes through *E*, and the motor begins to turn slowly. To increase the speed, more resistance is gradually inserted, until there is no magnetism remaining in field *C*, the motor *E* then runs at half speed, the voltage being that of the line. By still further moving the switch of the rheostat in a clockwise direction, the field *C* is reversed, and gradually strengthened. The voltage of the armature *B* is now gradually increased in a direction which assists the voltage of the supply mains, and as soon as the whole of the resistance is switched out, the voltage of the supply mains is doubled, and the motor *E* attains its full speed. This is the position of the switch, as shown in the diagram. It will be seen that, as the controller has only to regulate the field current, it may be of a very small size, and yet have a very large number of contacts, thus affording a very gradual control, and securing absence of that destructive sparking of the contacts which is so common with rheostats carrying large currents. Further, the space occupied by this controller is but a small fraction of that required by the rheostats used on the series-control system.

The loss in the motor generator has been ascertained by Messrs. Edward Lloyd, Ltd., from actual meter records, to be but small; while the loss in the controller varies from 0 at half speed, up to the maximum of only two per cent. at slow speed, or full speed, whereas, with the series control, as much as 95 per cent., or nearly 50 times as much, will be lost at slow speed. The machine can be reversed if desired, but in the case of Hoe presses, it is only necessary that this reversal should be applied at low speeds. For this purpose it is provided that the motor

generator is capable of giving a voltage slightly in excess of that of the line; so that, when it is in opposition to the line, this excess causes a flow of current through the armature *E*, which then rotates in a reverse direction.

The flexibility of this system is well illustrated in the three creeping switches which are placed round the machine at different points. These switches have seven or eight steps in parallel with the early steps of the controller, so that the machine minders may themselves operate the press at the low speeds required for fixing the plates and threading the paper before the actual process of printing begins.

The simplicity of the apparatus and the beauty of the control were very patent to us when, by the courtesy of Messrs. Geipel & Lange and Mr. G. Mascord, the chief engineer of Messrs. Lloyd, we were afforded an opportunity of inspecting the plant. The whole regulation of the speed and direction of rotation is effected by the small controller; there is only one small hand-wheel to work, which effects the whole of the operations in sequence, so that it is impossible, even for an inexpert attendant, to make any mistake. The controller is carried on a pedestal, which is fixed on the floor near the machine in the most convenient place; the main switchboard, which carries the measuring

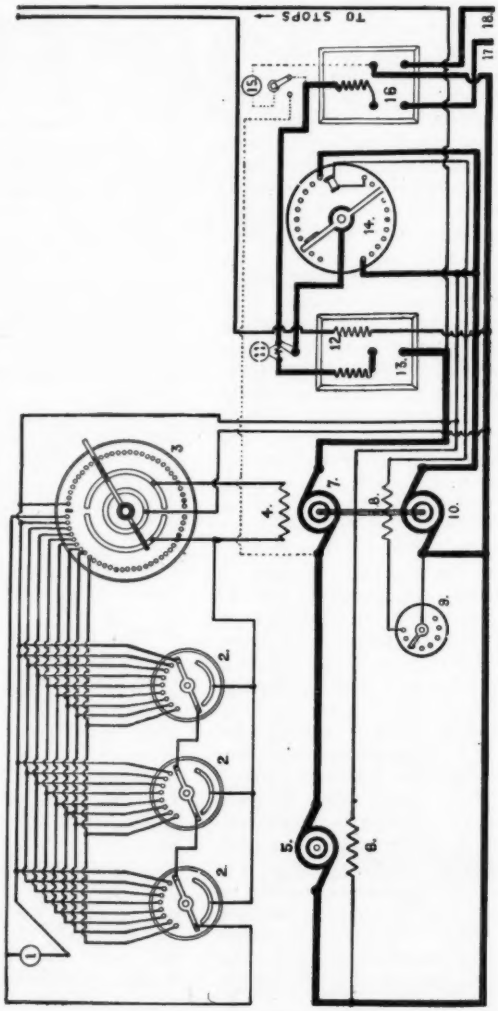


FIG. 2.—DIAGRAM OF COMPLETE CONNECTIONS.

1. Single-Pole Switch.
2. Creeping Switches (for Slow Speed).
3. Field Reversing and Regulating Switch.
4. Booster Reversible Field Coils.
5. Motor for Driving Machinery.
6. Motor Field Coils.
7. Booster.
8. Booster Motor Field Coils.
9. Field Regulating Switch.
10. Motor for Driving Booster.
11. Ammeter and Switch.
12. Emergency Tripping Coil.
13. Single-Pole Circuit Breaker.
14. Starting Switch for Motor.
15. Voltmeter and Switch.
16. Double-Pole Circuit Breaker.
17. Positive Supply Main.
18. Negative Supply Main.

instruments, etc., is fixed on the wall some distance off, out of the way, for it is not necessary for the attendants to use this board in operating the machine. As there is no large series rheostat, the heating of the coils thereof is avoided, and the plant will run for long and indefinite periods, even at the very slowest speeds, while the wear and tear of the coils in the rheostat and contacts are obviated. In fact, there would appear to be the lowest minimum of wear and tear, judging from the results of the working of the system, as, indeed, would be expected from the absence of shocks, jars, or disruptive sparking.

There is an additional advantage, which appeals more particularly to those who supply the power, that is, from the central-station engineer's point of view, in that, instead of drawing the full current from the mains at starting up, which, particularly in the case of large motors, caused unsteadiness of the supply voltage, the current required from the mains at starting is but a fraction of the full load current, and, further, that fraction is switched on gradually.

It may be of interest to add the following description of the signalling apparatus and switchboard arrangements, which, however, do not form a necessary part of the "Ward-Leonard" System. In order to signal to the attendant who operates the controller, a bell and indicator having three different coloured lights are fixed near the controller, which are operated by pushes fixed at various points round the machine. The colours represent "start," "full speed," and "stop," while the bell calls attention to a change in the signals. The colour of the light remains constant until another signal is sent.

In case it is necessary in emergency to stop the machine instantly, a circuit-breaker is provided, which is operated by pushes placed round the machine, alongside the pushes for signalling, so that the circuit may be automatically opened by pressing any one of these pushes, which instantly stops the machine.

The switchboard is of enamelled slate, mounted with a motor starter for the motor generator, an ampère-meter having a two-way switch, by which means the current supplied to the press motor, or the total current taken from the supply mains, respectively, can be measured, and a voltmeter with a two-way key, which permits the voltage at which the press motor is working, or the voltage of the mains, to be read. "Ward-Leonard" circuit breakers take the place of switches and fuses; so that, should an excess of current, due to a jam in the press, open the circuit, it can be quickly closed again when required, thus saving the loss of time due to replacing the ordinary fuse, an important consideration in the production of a paper.

The energy used is metered by a Vulcan watt-hour meter, which not only integrates the energy used by the usual dial, but also registers the rate at which it is used on a chart. Thus, measurements can be readily made, both of the power and of the energy used.

A roller shutter protects the switchboard from dust and grit when the press is not working.

The whole of the connections are clearly shown in the diagram (Fig. 2).

The whole installation was carried out by Messrs. Geipel & Lange, of Parliament Mansions, Westminster, who are sole licensees.

It may be added that the "Ward-Leonard" system of motor control is applied to drive various other classes of machinery, where its advantages particularly apply, such as passenger and goods lifts, travelling cranes, mining hoists, rolling mills, the training of turrets on Naval vessels, etc., for which purpose it has been very largely adopted by the United States Navy.

Workshop Practice

The attention of Works Managers, Foremen, and those under their charge, is particularly directed to this section, which has been designed for providing an opportunity of bringing practical ideas and experiences into print. What we desire to encourage is inventive capacity and originality. Send along particulars, accompanied by rough sketches, of emergency devices, jobs which have taxed your ingenuity, etc.; they are worth recording.

❀ ❀ ❀

A Lifting Appliance.

Erectors and others engaged in engine repairs often experience considerable difficulty in arranging lifting tackle, and frequently they have to improvise something from the odds and ends of the shop to meet their requirements. In the case of a cylinder liner to be fitted in place, we adopted the following expedient. The liner was bored and turned to size by the engine-makers after the old liner had been removed, and was then sent down to be fitted in its place, the fitting necessitating some amount of scraping and the consequent lifting in and out of the liner during the operations. The bearing strips were turned for a tight fit, and in order to secure this condition, the cylinder was heated by admitting a small quantity of steam from the boiler through the stop valve, whilst the liner was kept cool; expansion produced being quite sufficient to ensure a good shrinking fit. The lifting tackle was formed of cross-bars and eye-bolts, the iron used for the bars being 3 ins. by $\frac{5}{8}$ in., and composed of two pieces sliding on each other, and with slotted holes for the bolts shown on each side of the centre eye-bolt (Fig. 1). By this means they were arranged to suit different diameters. By the use of two plates at each end, slotted as Fig. 2, greater variation could be made.

Getting Rid of the Water.

In resheeting upper lift of 100,000 cub. ft. gasholder, considerable difficulty was experienced in getting rid of the water, owing to the tank *A*, which was of cast-iron plates 1 in. thick, being about 3 ft. below the level of the river. A No. 5 Pulsometer *B* was erected in the tank and, worked by a small vertical boiler *C*, quickly dislodged the water, but when it

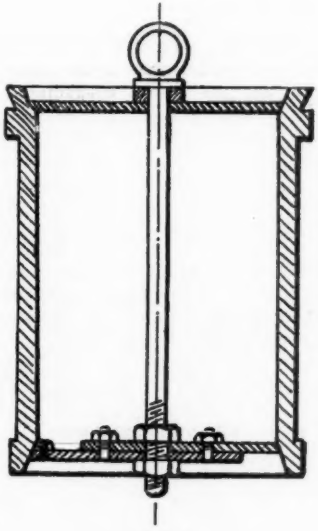


FIG. 1.

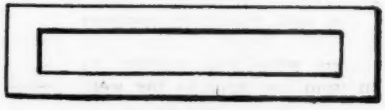
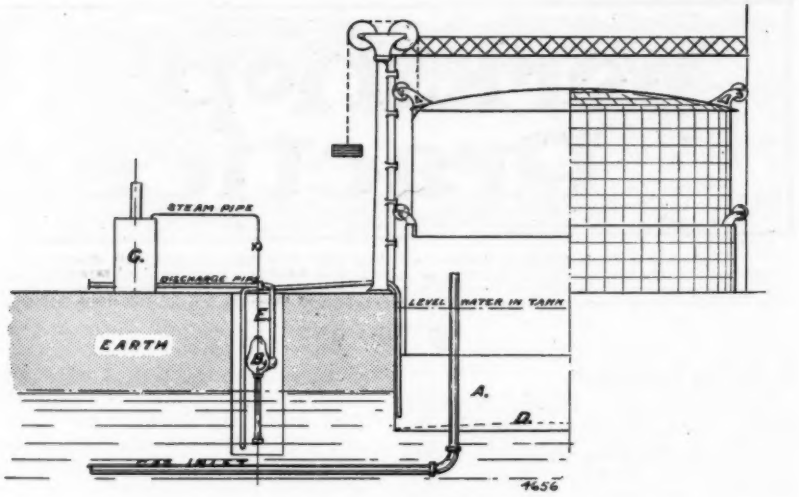


FIG. 2.

A LIFTING APPLIANCE.



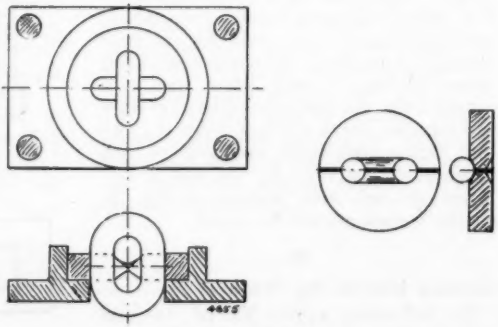
GETTING RID OF THE WATER.

was got to within 2 ft. of the bottom the plates in the centre rose to the extent of about 6 ins. (as shown exaggerated at dotted line *D*), owing to the pressure of the water underneath becoming greater than the pressure inside. When the engineer saw this he deemed it advisable to stop pumping in case some of the plates should burst. A box about 6 ft. sq., without bottom or lid, was got and banked up with clay puddle, then pumped dry with a hand pump, so as to allow a hole to be bored. Four 2-in. holes were then bored in this way, in order to lessen the pressure on the bottom, and a well *E* was also sunk in the yard to a depth of about 20 ft. The pulsometer was then shifted into the well to try and keep the water from pouring into the tank through the holes, but this could not be managed; however, it relieved the pressure to such an extent that the bottom of the tank gradually assumed its former shape. Three 3-in. syphons were then started to run from the tank to the well, and by keeping these constantly going, the water was kept sufficiently low to enable the job to be completed in a satisfactory manner.

S. AND B.

A Simple Chain Lock.

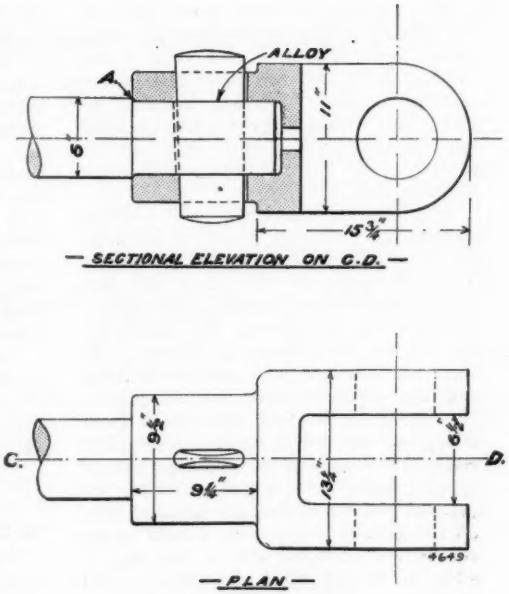
The accompanying sketches show a device resorted to, in place of using an eye-bolt or shackle. It was designed by the writer for use on a steam hoist of the straight-pull pattern. The cylinder was 20 ins. diameter by 11 ft. stroke, and a pulley on the piston-rod end worked in a



A SIMPLE CHAIN LOCK.

bight of the chain, giving a movement of 22 ft. The steam pressure was 50 lbs., and the cage weighed 1,800 lbs. alone, the usual weight lifted being 30 to 35 cwt. A ⅝ short-link crane chain was used, and as a shackle or eye-bolt would have been not only expensive, but difficult to fix on the timber framing, and would not have allowed for the necessary adjustment, the chain lock shown was put in. It consists of a casting as shown, with a circular rim on the upper face, and a cruciform hole cored through to pass the chain. Within the circular rim lies a steel plate—shown on the right—which is first drilled with two holes to match the sides of the link and then sawn asunder, the web being thinned, as shown in cross-section, to allow the "quarters" of the link to bear. A ½-in. set-screw was put in to hold the plates down. Strength for strength, it is cheaper than a shackle, especially if fixing is reckoned in, whilst it will hold a chain at any point without damaging it.

THE BOGEY MAN.



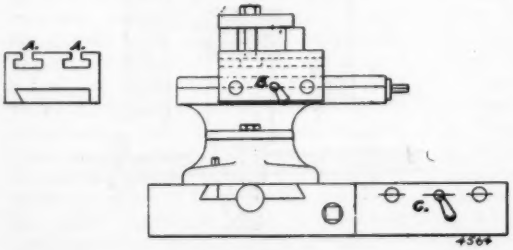
SLACK PISTON-ROD.

Lathe Improvements.

The illustrations show three improvements which I thought were necessary to a new lathe. The alterations, marked *A B C*, are shown in Fig. 1, the first, *A*, being the substitution of T-head slots in the top slide in place of the fixed studs usually inserted by tool-makers. This gives the advantage of changing tools without having to run off the nuts when cutting in different directions. Alteration *B*, substitution of handle for spanner when tightening slide, and a similar form of handle, *C*, applied for the same purpose to saddle.

S. F.

[Best adapted to a heavy lathe.—ED.]



LATHE IMPROVEMENTS.

Slack Piston-rod.

The piston-rod and cross-head shown in the sketch had been running for a great many years without being taken apart, but upon inspection it was found to be necessary to re-turn the rod. Great difficulty was experienced in taking the rod apart from the cross-head, the latter being both heated and hammered a good deal before the rod was removed. The rod was corroded where it fitted the head; and before being replaced all this corrosion was cleaned off. And now the rod, which was originally a parallel driving fit, went into the head quite easily.

After running for some weeks the rod wore slack. Owing to the engines being wanted night and day at that time, it was impossible to stop for more than a few minutes together. We had, therefore, to be content with putting a washer behind the rod and keying up to that; unfortunately this did not make any great improvement.

When next examined, the average amount of wear was found to be $\frac{1}{8}$ in. on the diameter. To put this thoroughly in order again, the cross-head required to be re-bored and bushed, and the rod skimmed up to a driving fit. Although the engines were more at liberty now, there was not sufficient time to do this, and the expense would also have been very great, as we had discovered when taking out the rod to be re-turned. The rod is 25 ft. long, and has two large pistons (36 ins. and 40 ins.) keyed on to it. To take the rod out of the cylinders and take off the pistons, meant a day's work under the best conditions, and it was impossible to foresee what difficulties would crop up.

It was decided to try what would be the effect of running some metal round the rod. An alloy was made as follows:—9 parts by weight of lead, 2 of antimony, and 1 of bismuth. This alloy expands on cooling.

The rod was oiled and placed in the cross-head about $\frac{1}{32}$ in. back from its correct position. The cotter-ways in the rod and in the bottom of the cross-head were clayed up, as was the space between the end of the rod and back of the cap. At the end *A* a piece of asbestos cord was wound round the shaft and caulked into the cap. A fire was built in under the lot, and red-hot heaters (lumps of iron) placed on top of the cap. When a temperature rather below the melting point of the alloy was reached, the metal was melted and poured round the shaft through the cotter-way in the top of the cap, which had been left open for that purpose. When cold, the cotter was placed in position and driven home with a heavy sledge; the rod shifted about $\frac{1}{64}$ in. Since then (about nine months ago) the engine has run without giving trouble.

From the experience gained that time, it seemed probable that the alloy would be improved by having a greater proportion of antimony and rather less of bismuth, to make the alloy harder.

F. H. Palmer.

A Tapping Device.

At Figs. 1 and 2 are shown methods of tapping holes when too short to allow a tap with any appreciable starting taper to be used, and the shape of the piece makes it impossible to screw in the lathe. A long plug tap was made having a leading tail or screw of smaller diameter than the tap, but cut into a thread of the same pitch. This worked in a bar cramped on the casting, and so forced the tap to enter and do its work, as at Fig. 1. Fig. 2 shows the same principle applied to a case where there is no convenient hole through which the leading screw could work.

J. W. B.

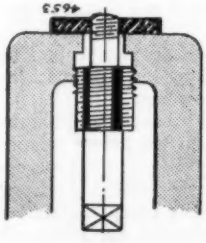


FIG. 1.

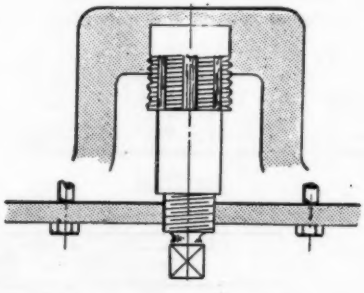


FIG. 2.

A TAPPING DEVICE.

WORKSHOP QUERIES AND ANSWERS.

WILL some of our readers kindly answer the following?

Tube Drawing.

I have an aluminium tube, 12 ins. long, $\frac{1}{2}$ in. diameter, ·05 in. thick. How can I reduce it to a gradual taper of, say, $\frac{1}{4}$ in. at the other end, keeping it a uniform thickness throughout? J. B.

Building Commutator.

Which is considered the better way to build a commutator: on its sleeve cold, and heat it afterwards; or to heat the sleeve first, before placing the commutator on it? As there is a diversity of opinion on this point, I should like to have some of our readers' opinions on it. E. C.

Polish on Turned Work.

What is the cause of the polished appearance of wrought iron and steel if soapsuds are used as a lubricant when turning the same?

Alterations in Dynamos.

In the October issue, "Temporary Repair to Dynamo," it was suggested to cut out a defective field coil and work with the remaining good one. How to apply this to multipolar machines constitutes an interesting problem, as it is more applicable to motors than to dynamos. The latter being used to a great extent for lighting, necessitate the maintenance of a standard voltage. The former adapt themselves more readily, so more latitude is permissible in running. In the case of a four-pole motor, should it be run as a bi-polar, lifting one pair of brushes off the commutator, disconnecting a pair of coils, using the diagonally opposite pair, and should the disused pair of coils and pole pieces be removed? In similar cases with six polar machines, what is the best arrangement of brushes and field coils?

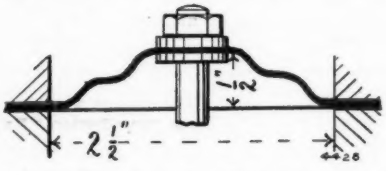
W. W.

Wood *v.* Iron Pulleys.

A great many manufacturers are fixing on line shafts wooden pulleys of American make, the makers of which claim better driving power from their use. I should like to know if tests have been made at any time which have proved their superiority over iron ones, and if they really are so? S. F.

Construction of Diaphragm.

A metal diaphragm, $2\frac{1}{2}$ ins. diameter, and similar in form to the illustration, is required to stand a pressure of 350 lbs. per square inch on its under side. It is supported not only at its circumference, but also by the stay at the centre. It is



desired that when the diaphragm is thus acted upon, it shall be held by the stay with its centre half an inch from its normal position, so that when the pressure on its two sides is equalised, and the centre stay released, the diaphragm shall spring back half an inch. How should the diaphragm be constructed? DIAPHRAGM.

Foundry Practice.

How can the proper casting temperature of an alloy be best determined?

What are considered the best methods of mixing brass-founders' alloys?

Give an easy rule for weighting moulds.

Describe the moulding process known as "La cire perdu" (The lost wax).

What constitutes a "bronze" in modern engineering parlance and technical nomenclature?

Which is the best way to "kill" (to prevent liquation) lead in brass alloys?

J. F. B.

Electricity Meters.

The prevailing practice with regard to consumers' electricity meters is to instal them, and then leave them to take care of themselves for five to ten years. When they are deemed to be so inefficient as to render the substitution of new ones desirable, the makers will not take them at any price, so they help to swell the scrap heap. Has any means been devised for overhauling, cleaning, or repairing them that does not entail an undue allowance of time? If the parts are taken apart the calibration of many types are altered, which proves rather awkward.

W. W.

Wetting Tramway Rails.

Electric tramway authorities are disposed to constantly sprinkle the rails with water, even in broken or unsettled weather, often before they are entirely dry from the last rain. What renders this seemingly undue allowance of moisture on the rails desirable?

W. W.

Worm Gearing.

Why does worm-gearing admit power to be transmitted in one direction only? Please explain with drawings. Show action of teeth and effect of small pitch of worm teeth.

W. W.

Atmospheric Change.

Wanted, a clear and concise explanation of the atmospheric changes that lead to the load increasing suddenly on electric light stations, whatever the time or clearness of the day may be. Or does the presence of a film of moisture on glass render it less transparent to light?

W. W.

Gas and Oil Engines.

What are the relative advantages of gas and oil engines as regards cost (initial and running), up-keep, working, and efficiency?

W. W.

The guinea prize was awarded last month for the contribution "Extension of Line Shafting."

Engineering Abstracts

❀ ❀ ❀

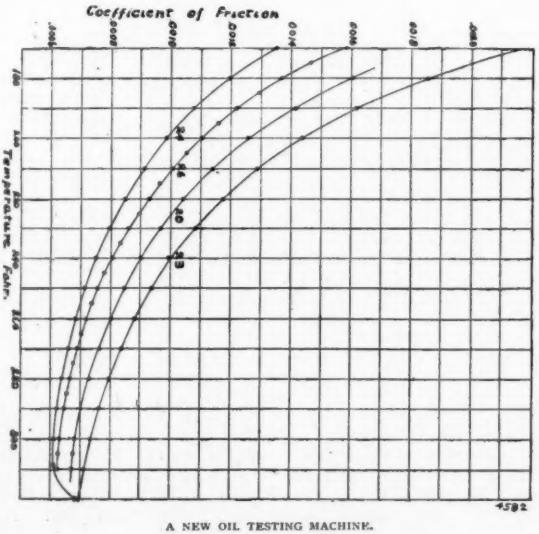
MATERIALS AND MEASUREMENTS.

International Congress upon Methods of Testing Materials (Paris 1900).

THE International Congress upon methods of testing materials of construction, held in Paris in 1900, has been followed by the publication of six quarto volumes of valuable reports. The numerous and voluminous papers submitted to the Congress are divided into three groups: the first dealing with the molecular constitution of bodies, and methods of testing; the second with metals; and the third with other materials of construction. A convenient summary has now been issued, in Belgium, of three communications relating to timber, which present a reliable *résumé* of existing knowledge with regard to this material.—**M. F. Zanen,** *Proc. Assoc. des Ingénieurs de Gand, Dec. 1902.*

A New Oil Testing Machine.

IT has become well recognised by experimenters that the value of lubricating oils and greases depends upon viscosity and body. The former property is well understood and capable of precise measurement, but the latter property, or combination of properties, is not so well understood, and it is probably an intensified viscosity in that part of the fluid within the region of attraction of the surface molecules of the metal employed. One of the most frequent causes of contradictory results in friction tests is that the effect of viscosity may readily mask the effects of body, and another cause is found in the changes in the rubbing surfaces which always take place with wear, and which must, therefore, accompany any test for body. The author describes a new testing machine for lubricating oils, available for the independent investigation of viscosity and body, and the apparatus is serviceable also for tests under any intermediate condition. For tests involving perfect lubrication (friction due to viscosity only), the test journal used is 1⅛ in. diameter, of tool steel, hardened, ground, and polished. The brasses are sectors cut from a ring finished in the lathe, each having an arc of about 120 degs., and a length of 2 ins. These brasses are fitted with some care, so that when perfectly clean they may be made to adhere to the journal after the manner of well-fitted "surface plates." In making tests, care is taken to prevent wear of these parts, which are used only under such loads that the oil film effects complete separation of the surfaces and entirely prevents wear; the load is always relieved before starting or stopping the journal; and, finally, a friction device in the driving coupling safeguards the journal from motion against excessive friction. These



A NEW OIL TESTING MACHINE.

precautions against wear are necessary to insure the constancy of results. For tests for comparing oils with respect to body or oiliness, the best results have been obtained by the use of a hardened and polished steel journal ¼ in. in diameter, running between two brass bearings about 1 in. long; on this small journal pressures up to 8,000 lbs. per sq. in. may be applied if necessary. The samples of oil to be compared are contained in small brass cups placed inside the case and surrounding the test journal, each cup having a wire for transferring oil to the journal; the case, samples, and journal are together heated to any desired temperature. Among the specific results thus far obtained, the four cylinder oils whose variations of viscosity with temperature are shown in the diagram were found to have body in the same order as viscosity; the body being tested at 180 degs. and 312 degs. Fahr. Again, samples of castor, lard, olive, and sperm oils were placed in the order named by the body test, which order was the same as that of their viscosities. It thus appears that body is in some way related to viscosity, but the relation must be quite different in the mineral oils and the fixed oils.—**A. Kingsbury,** *Trans. Amer. Soc. Mech. Eng., Dec., 1902, Vol. XXIV.*

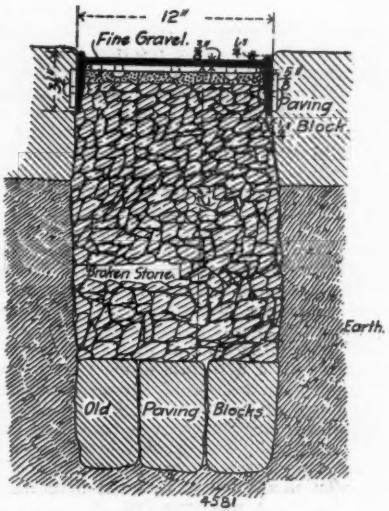
CONSTRUCTION.

Armoured Concrete.

In concluding his series of articles on this subject, the author deals with the most suitable methods of executing compression members in *béton armé* and *béton fretté*, pointing out the importance of preserving elastic symmetry in columns and struts of more or less cylindrical section. Lack of symmetry is directly productive of curvature and distortion, but symmetry is difficult of attainment in members moulded in a horizontal position, owing to the differences existing between the upper and lower layers of concrete, in consequence of tamping and the unequal distribution of the materials. Vertical moulding is therefore recommended for all members intended to support axial loads, and it is also very desirable that the operations necessary should be performed under cover so that rain or the heat of the sun may not exercise a prejudicial effect. In order to guard against defects, all members should be submitted to examination by tapping with a hammer and by weighing. The fact is that for any given mixture, the co-efficient and limit of elasticity, as well as the resistance, vary in the same ratio as density, and are in proportion with the sonorousness of the material. Advantages derived from the practice of moulding columns and beams of armoured concrete in a properly equipped workshop, are that more reliable products may be obtained, that testing operations can be better performed, that the preparation of the members can be commenced during the execution of preliminary works upon the site of the intended structure, and that the members made in advance have every opportunity of being thoroughly hardened before use. Joints between pieces of *béton armé*, with longitudinal rods, may be effected by the employment of sockets into which the projecting ends of the rods can be grouted, and in the case of *béton fretté* supplementary netting of fine iron wire may be used with advantage to give ample strength to the joints. In the case of compression members liable to heavy strains, it is advisable to use at least 450 kg., and often 600 kg., of cement per cubic metre of concrete, in order that all the voids may be adequately filled. The author considers that for longitudinal armatures hard steel is the most suitable, while for network ordinary iron or mild steel is the better material. As a general rule, the percentage of metal may be between 0·01 and 0·02 for longitudinal armatures, and between 0·02 and 0·03 for network. Of two pieces of reinforced concrete formed of the same quantities of similar materials, that made with network has much greater resistance and enormously more ductility than that having an armature of the ordinary kind. The approach of danger in the first type will be indicated in advance by scaling of the surface, which it is shown has practically no influence upon the general resistance of a member; and in the second case no warning is to be expected before rupture, or no indication of excessive strains placing the structure in danger. The processes of manufacture and erection outlined by the author are practically analogous to those followed in constructional ironwork, and seem to provide all reasonable guarantees of sound and reliable work.—**M. Considère,** *Le Genie Civil, Dec. 6, 1902,* pp. 82-86.

A Steel Roadway in New York.

An experimental steel highway has recently been laid in Murray Street, between Broadway and Church Street, New York. At present there is only a single steel track up the centre of the street, on which loaded teams coming from the North River piers are given the right of way. The accompanying sketch shows a section through one of the rails, the depth of foundation shown, however, being somewhat greater than that finally adopted. The rail section is very similar to



STEEL ROADWAY IN NEW YORK.

that of a 12-in. channel, the main difference being that there are slight ridges along the outside edges of the wearing surface, which tend to keep the wagon wheels in the track. The rails are in 40-ft. lengths, being riveted together by means of three splice-plates, one on the other side of the main web of the channel, having three rivets for each rail, countersunk on the top surface. The other two plates connect the flanges, each with two rivets to a flange. The rails are spaced 5½ ft. apart, centre to centre, and every 13½ ft. longitudinally they are tied together with ¾-in. rods, bolted through the outside flanges. The foundation for the rails is 12 ins. of broken stone resting on the old paving blocks replaced by the rails. The under surfaces of the rails were coated with tar and the rails then bedded on a thin layer of fine gravel. In addition to this roadway in Murray Street, which will be subjected to the heaviest kind of traffic, it is proposed to lay another stretch of the steel road on Seventh Avenue, in the neighbourhood of 120th Street. A trial will also be made on some dirt road, for the advantages of the steel rail are considered to be as great for a country road as for city streets. At the present price of steel, it is stated that the rails can be furnished for 4,000 dols. per mile. The cost of construction would of course vary with local conditions, and as the work so far done is experimental and workmen had to be taught how best to perform the various operations of laying the track, no reliable estimate has been made as to the total cost of laying this roadway.—*The Engineering Record, Dec. 13, 1902*, p. 562.

Le Verre Armé.

ONE well-known property of glass is to be found in the facility with which it may be welded to metals such as gold, platinum, nickel, copper, and iron, a property which is utilised daily, and gives the means of imparting to glass those qualities in which it is naturally deficient. The combination of glass with any one of the metals mentioned gives the permanence which is lacking in glass alone, and results in a new product possessing distinctive properties, corresponding with those which have long been desired. For economic and other reasons iron has been chosen for the reinforcement of glass, and it is employed in the form of a network of fine wire only slightly modifying the appearance and transparency of the glass in in which it is embedded. The properties given by the incorporation of glass with metal are cohesion and tenacity. From the first of these properties it results that if a sheet of reinforced glass be broken or cut, the fragments remain joined one to the other and cannot be separated unless the iron network is cut by a suitable tool, or broken by bending backwards and forwards. From tenacity, in a manner analogous to that observed in connection with reinforced cement, it results that a relatively high resistance to flexure is imparted, a property possessed to a very limited degree by ordinary glass. Moreover while glass breaks suddenly without giving any indication of approaching failure, reinforced glass cracks and splits, but the fragments are always joined together by the iron network. The resistance of the combination when heated is not less remarkable. It is known that under a sudden change of temperature glass cracks; it is the same with reinforced glass, but, as in the case of a blow, the pieces remain in contact so that continuity is not broken and none of the pieces separate from the sheet. It will therefore be seen that reinforced glass is specially serviceable in fire-resisting construction. It may be employed as a substitute for sheet iron, or sheet iron and wood in the construction of doors and shutters intended to prevent the spread of fire, and it really offers greater security than either of the materials mentioned Reinforced glass offers, by reason of its tenacity, a safeguard of another nature which may be utilised against theft or burglary from the windows of houses and shops.—**Léon Appert,** *Proc Soc. Ing. Civ. de Frante, 1902*, pp. 470-506.

IRON AND STEEL.

The Manufacture of Open-Hearth Basic Steel.

In a paper read before the Cleveland Institution of Engineers, the author said that the advent of basic steel had caused such radical changes in the design of steel furnaces that Siemens would scarcely recognise his handiwork. In designing a furnace the engineer should ever keep two chief points before him—the strongest possible construction and great heating capacity. Sufficient distance should be given between port blocks to ensure good combustion in the melting rather than in the regenerator chambers; for a 30-ton furnace he would not have less than 28 ft. between port blocks. The ports should be greater in width than in height; a port area of 320 ins. should be 23 ins. wide by 14 ins. high rather than 18 ins. square. Thus the flame would be spread out more over the bath, giving quicker work. For a furnace having 28 ft. between port blocks the author suggested two gas ports, each having an area of not more than 250 ins. The pitch of the gas ports should not be more than 2½ ins. per foot of length, so as to have the flame pass close to the metal from one end of the furnace to the other. As regarded the exact height desirable for the roof in an ordinary furnace, the author considered that 5 ft. 6 ins. should be quite a sufficient distance from slag line to centre of roof. For quick work the bath should have a mean depth of not more than 18 in., as the deeper the bath the slower would be the melting, the slower the reducing and refining, and the longer it would take to reach the high temperature necessary for tapping. He did not agree with the generally accepted theory that cubic contents alone governed the capacity of regenerator chambers, irrespective of whether these cubic contents were obtained by great length, width, or depth. He had never seen regenerator chambers too deep, but often too shallow. Whenever he had increased the depth he had always received quicker work from the furnace. As to the relative proportion of gas and air for regenerator chambers, steel men differ widely. He had got the best work from chambers having the proportion of 1 for the gas to 1·37 for the air. The temperature at the top of the air-chambers was as high as 2,150 degs. Fahr., while the gas chamber always worked a shade cooler. Under the basic process they had four recognised sub-processes:—Cold metal, direct metal, Talbot, and Bertrand-Thiel. The first two were the more common, and thus far had held their own against the others. The cold metal process was obviously more expensive, but as there were many steel furnaces that were not connected with blast furnaces, it had to be resorted to. There was in Great Britain a further objection to the cold metal process—the pig-iron makers did not cast the iron in chills, and when remelting, 300 lbs. of limestone had to be charged merely to take care of the sand that adhered to each ton of pig-iron. The cold metal process permitted of better sampling of the charge. Whenever the conditions were such as to make it feasible the direct metal process should be adopted, as that would give a far greater production without a corresponding increase in the cost of installation in the steel plant. Mr. Talbot had proved that it was possible to hold molten steel in a furnace for an indefinite time. If he required a first-class product from very impure stock he would seriously consider the Bertrand-Thiel process, but he did not intend to admit that he was convinced that the Bertrand-Thiel process would give a greater production of steel per unit of cost of installation and labour than the direct metal process. If it was true that, on account of the high silicon, phosphorus, and sulphur found in English basic iron, it was impossible for steel furnaces to make more than eight or nine charges per week by the cold metal process, or thirteen by the direct metal process, then it was time to seriously consider the installation of the Bertrand-Thiel process.—**C. H. MacMillan,** *The Iron and Coal Trades Review, Jan. 23, 1903,* pp. 236*b*—236*d*.

PRIME MOTORS.

The Waste-Heat Engine.

It is clear that the efficiency of a steam-engine may be increased by raising the temperature of the source of supply or by lowering the temperature of the exhaust. Attempts have been made in the latter direction by employing sulphurous anhydride instead of cooling water in the surface condenser. At the ordinary temperature, sulphurous anhydride (SO_2) is a colourless gas, which can be easily liquefied under a pressure of about 25 lbs. per square inch. Fig. 1 shows the arrangement of a triple-expansion condensing engine fitted with a sulphurous anhydride heat-saving apparatus. The condenser in this case has to be made specially for the liquid sulphurous anhydride, which passes in as indicated by the arrow. The steam is condensed, and a vacuum is maintained on the low-pressure cylinder by means of an ordinary air-pump. The heat given up by the steam in condensing serves to vaporise the

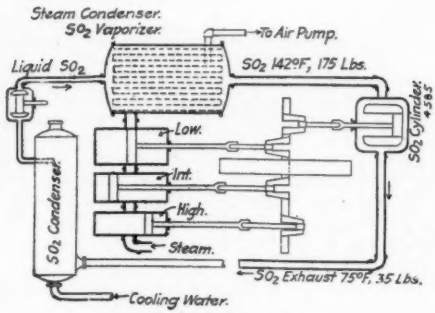


FIG. 1.—THE WASTE-HEAT ENGINE.

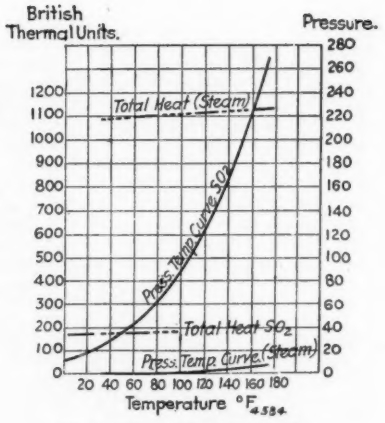


FIG. 2.—THE WASTE-HEAT ENGINE.

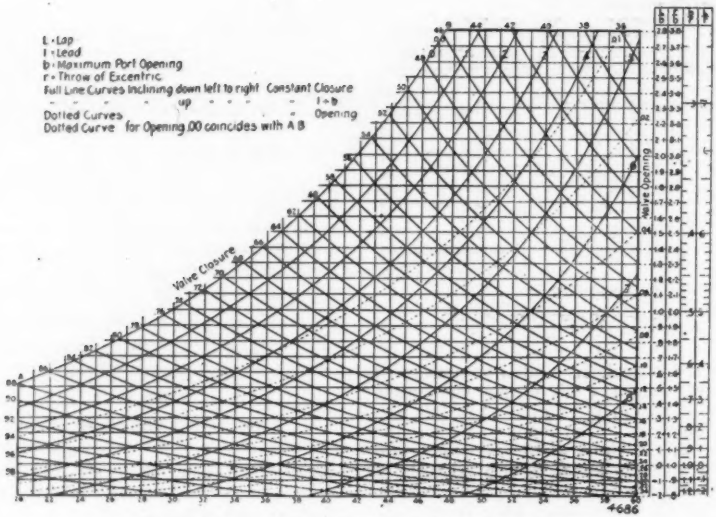
sulphurous anhydride, and the pressure of something like 175 lbs. of the sulphurous anhydride vapour is maintained in this surface condenser. That vapour passes to the cylinder at the right, where it is used; and from the cylinder at the right it exhausts to the condenser at the left, which is nothing but a surface condenser. After being condensed here under a pressure of 40 lbs., the liquid is pumped back into the vaporiser, thus making a complete cycle. In Fig. 2 the pressure curves of the SO_2 and steam are given. At 180 degs. Fahr. the pressure of the steam is only 7·5 lbs., whereas the pressure of sulphurous anhydride is something like 270 lbs. At 100 degs. Fahr. the pressure of sulphurous anhydride is something like 80 lbs., and its total heat is very much lower than that of steam. On the same cut the total heat of a pound of steam ranges in the neighbourhood of 1,100, and of sulphurous anhydride 190. This, of course, will make it evident that it is possible to vaporise sulphurous anhydride and get excessive pressures with it, the fact being that the total heat of sulphurous anhydride is low, and its pressure rises rapidly with rising temperature. From the table below it will be seen that some noteworthy results have been obtained by the employment of sulphurous anhydride in the manner indicated. The device for utilising waste heat can be attached to any existing steam-engine, and it is also applicable to the recovery of waste heat from the exhaust of gas engines, and in saving the heat of the flue gases leaving a battery of boilers.—**Prof. E. F. Miller,** *Proc. New England Waterworks Association, Nov. 12, 1902.*

Graphical Chart for Valve-gear Problems.

THE purpose of the present paper is to describe a form of diagram or graphical representation of the relations involved, which, once drawn, shall contain the solution of all possible problems within the usual working range, and which shall thus present readily to the eye the results of slight modifications or adjustments in the data. With such a diagram the solution of a problem in valve gear

Extract from tests of triple-expansion condensing engine with sulphurous anhydride heat-saving engine:—

Condition of Steam.	Superheated.								Saturated.
Steam Temperature degs. Fahr.	534	588	590	583	579	579	590	574	373
Speed revs. per min.	139·6	136·3	143·5	137·4	145	145	148	148	149
Indicated horse-power	132·1	125·2	154·2	101·6	145·3	144·5	161·0	163·2	156·3
Steam per I.H.P. { Steam Engine	**12·5**	**11·2**	**12·2**	**14·4**	**13·6**	**13·8**	**13·2**	**13·1**	**16·4**
Steam per I.H.P. { Combined Engine	**9·7**	**8·36**	**8·6**	**11·05**	**10·12**	**9·86**	**9·55**	**9·85**	**11·5**
Test No	1	2	3	4	5	6	7	8	9


L = Lap
l = Lead
b = Maximum Port Opening
r = Throw of Excentric
Full Line Curves inclining down left to right Constant Closure
" " " up " " " l ÷ b
Dotted Curves " Opening
Dotted Curve for Opening .00 coincides with A B
Valve Closure
Valve Opening
4686

GRAPHICAL CHART FOR THE SOLUTION OF VALVE-GEAR PROBLEMS.

design, at least to the same degree of accuracy as with the Zeuner or Bilgram diagrams, becomes merely a matter of reading the values desired directly from the diagram, and without any additional construction whatever. Mathematical details showing the development of the diagram are given in an appendix, and the following is a general description of the diagram itself, which is reproduced in above:—One of the vertical scales on the right gives values of L divided by b, or lap divided by maximum port opening, or, in other words, of the lap for a maximum port opening of one inch. Other sizes are then readily found by proportion. The horizontal scale gives values of δ, the angular advance. The full line curves sloping from the left upward to the right give the relations between $L \div b$ and δ, each curve for a constant value of $l \div b$ or lead divided by maximum port opening as marked at the right-hand or upper extremity. Similarly, the full line curves sloping from the left downward to the right give the relations between $L \div b$ and δ, each curve for a constant value of valve closure as marked at the upper or left-hand extremity. The dotted curves sloping from the left upward to the right give the relation between $L \div b$ and δ, each curve for a constant value of the valve opening being marked at the upper or right-hand extremity. It will be noted that the line for opening at o, or the end of the stroke, coincides with AB, the line for o lead. This diagram serves to answer all questions involving lap, lead, cut-off, compression, exhaust-opening, steam-opening, angular-advance and maximum port opening.—**W. F. Durand,** *Jour. Am. Soc. Nav. Eng., Vol. xiv., No. 4,* pp. 1141-1150.

Entropy Analysis of the Otto Cycle.

THE object of this note is to call attention to the advantages of submitting all heat-engine records to the entropy analysis, and to the ease with which this may be done in the case of tests of gas engines of the Otto type. The note is based upon the tests submitted to the Society at its meeting of December, 1900. This particular test is chosen because it is representative of first-class work on a standard engine, all the particulars of which are already published. The writer has translated the sample indicator-cards published in vol. xxii. of the *Transactions*, pp. 157-162, into entropy-temperature diagrams, some of which are reproduced in his paper. It is pointed out that the general form of entropy-diagram expansion-curve from the Otto gas engine is identical with that normally produced by the non-jacketed steam-engine, where there is no possible source of supply of heat to the steam, except from heat already stored in the walls by the working fluid at the beginning of its cycle. The author submits that no observer of a gas-engine test, any more than of a steam-engine test, has done his proper duty by his task until he has

submitted his results to the entropy analysis. No other person than he, with his intimate knowledge of all conditions, can possible do it so accurately or intelligently. Since the task is often avoided for fear of its burden or its mystery, the author appends a facsimile of the work involved in deriving the diagrams reproduced in his paper.—**S. A. Reeves,** *Paper presented at the New York Meeting, Proc. Am. Soc. Mech. E., Dec. 1902, Vol. xxiv.*

DYNAMOS, MOTORS, etc.

Motor Speed Control by Variable Reluctance.

As far as the writer is aware, a patent issued to Thomas A. Edison in 1882 was the first patent ever issued covering adjustable means for governing the field strength in a dynamo-electric machine by varying the reluctance of the magnetic circuit. After referring to later devices of similar nature, the writer says, that the variable-reluctance methods cited and the use of the shunt rheostat present about equal advantages in many motor applications in which only a small range of variation is required. For controlling the speed of motors, the chief drawback in all the methods referred to is the narrowness of speed range within which the motor may be operated without prohibitive sparking. The exact percentage of speed variation obtainable by the use of field resistance is different in different machines having the same nominal rating, the generally accepted limit within which it is feasible to increase the speed of a motor by the use of resistance in the shunt circuit being 33 per cent. The narrow limit in question is due to inadequacy of the fringe at the pole tips, but if means are employed by which the flux at the pole tips is maintained practically constant, irrespective of changes in the total induction in the pole piece, then the speed may be materially increased without causing sparking at the commutator. This result is secured in the motors built under the Johnson patents, in which the speed variation in machines of 10 h.p. and over is fully four times as great as can be obtained by field resistance, or by the variable-reluctance methods before described. No essential difference exists between the special motor and those of ordinary design except in the construction of the pole piece, which is made so that it forces a gradually increasing proportion of the total magnetism down to the pole tips, the entire flux being delivered directly over the pole tips when the plunger is raised to the highest position. There is no reason why the machines described, operating at minimum speed, should be less efficient than any other motor of similar speed and capacity; and with an increase in speed of 125 per cent., they carry the full load with an efficiency about four per cent. less at maximum than at minimum speed, the reduction in efficiency being due to increased friction and iron losses at the high speed. As the speed

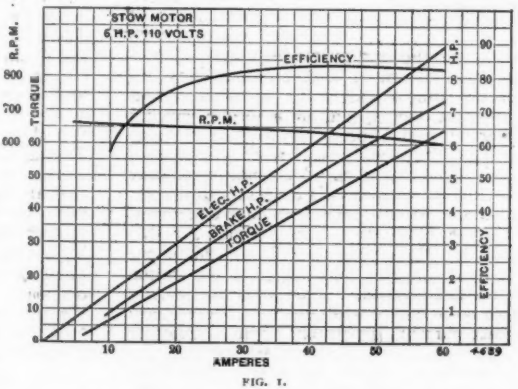


FIG. 1.

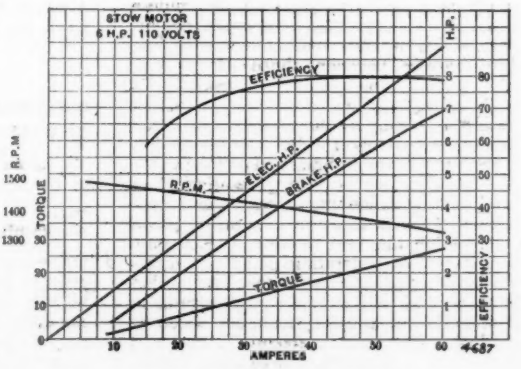


FIG. 2

MOTOR SPEED CONTROL.

control is accomplished without the use of resistance either in the field or armature circuit, the C^2R losses for a given load are practically unaffected by the speed. Figs. 1. and 2 respectively show the action of a 6-h.p. motor when operated at minimum and maximum speed, these curves showing the relation of current input to the speed, torque and efficiency. It will be seen that the motor described in this paper differs from all others in that, with constant potential at the terminals, it carries its full rated load at any imaginable speed within the limits of 125 per cent. variation, with an efficiency practically independent of the speed at which it is operated.—**G. F. Pickard,** *Am. I. E. E., Vol. XIX., No. 9, Nov. 1902,* pp. 1517—1527.

Variable Speed Motor-Work on Three-Wire System.

THIS paper gives a description of the operation of variable speed direct-current motors on the three-wire system. There are different classes of variable speed motor-work, but the one over which most discussion has arisen is that for machines requiring approximately the same maximum output at any speed, or a torque varying inversely as the speed. This class includes most of the machine-tool work where automatically constant speed regulation on any notch of the controller is especially desirable. Some companies and writers have demanded the use of multi-voltage systems for this work, but the author describes in this paper the operation and advantages of the simple three-wire system. The generator mostly used is the "three-wire generator," or ordinary direct-current generator having collector rings connected to the armature winding like a two-phase rotary converter. The leads from these rings are connected to auto-transformers or balancing coils, the middle points of which are connected to the neutral wire, which is thus maintained at a voltage midway between those of the outside wires. The motor is wound for single voltage, or for the two voltages of the system, according as the variations of speed required are narrow or wide. The advantages of the system are summarised as follows :—(1) Simplicity, not only in generating plant but in transmission lines, motors and controllers ; (2) Efficiency in generating plant, transmission line and motor ; (3) Economy in first cost of generating plant and transmission lines ; (4) Constant speed regulation from no load to full load ; (5) Smoothness of operation in changing from one speed to another. The author recognises, however, that where a constant torque over a wide range of speed is required, the multi-voltage system has some advantages. —**N. W. Storer,** *Trans. Amer. Inst. E. E., Dec. 1902, pp.* 1553-1559.—*H.*

Excitation of Asynchronous Generators by Static Condensance.

THE author discusses some of the consequences of the fact that an induction-motor when driven above synchronism becomes an asynchronous generator, and is capable of restoring power to the supply system. It may be operated in parallel with synchronous alternators, and shows no tendency to hunt, and may be thrown upon the system without being first brought into synchronism. When thus operated its exciting current is obtained from the synchronous alternators, while it supplies current to the line. A number of synchronous generators may be operated in parallel with a single synchronous alternator, the last machine being used to regulate the e.m.f., supply the wattless currents, and, if need be, to assist in carrying the load. Static condensance may be substituted for the synchronous motor as a source of exciting current for the asynchronous generator; and the performance of the latter is then strikingly similar in many respects to that of the shunt-wound direct-current generator. The author discusses some of the theoretical considerations of this arrangement, and adds that all his statements have been fully verified by tests upon commercial induction motors with squirrel-cage secondary windings. Since even a non-inductive resistance drop of e.m.f. in the generator windings under load current causes a slight decrease of the current in the exciter circuit under the lessened terminal e.m.f., the best regulation is obtained when the condenser is connected across one set of windings and the load placed across an independent set.—**A. S. McAllister,** *Elec. World* (N.Y.), Jan. 17, 1903, pp. 109-110.—*H.*

BATTERIES, ACCUMULATORS AND ELECTRO-CHEMISTRY.

The Accumulator.

THE author discusses briefly the principles of the accumulator, and sets out the conditions which must be fulfilled by any accumulator which is to stand comparison with those actually used. With these as guide to prevent useless experiments or speculations, he then enters on a theoretical discussion of the different points to be considered in seeking to arrive at a practical accumulator other than the lead-cell so universal in practice. These points are four in number: (1) the

electromotive force obtainable from any chosen couple; (2) the energy of charge and of discharge; (3) the resistance of the chosen electrolyte; (4) the solubility of the electrodes in this electrolyte. In the present paper only the first of these points is considered, the others being kept for a subsequent article. The author arrives at the theoretical e.m.f. obtainable from the chosen couple by finding from thermo-electric considerations the heat of combination of the compound constituting the electrolyte and the thermal equivalent of the volt, and dividing the first by the second.—**J. Izart,** *L'Electricien, Jan. 24, 1903,* pp. 55–57.—*H.*

Resistance of Electrolytes.

IN this article a summary is given of the different methods which have been proposed and used for the determination of the resistance of electrolytes. The main difficulty is the elimination of polarisation effects, and different experimenters have tried different ways of getting rid of this trouble. Wheatstone and others took observations with electrodes a certain distance apart in the electrolyte, and then again at a shorter distance; but this is inaccurate, as the same condition of the electrodes cannot be guaranteed in both cases. Carl Hering keeps the electrodes partitioned off by porous partitions from the main body of the electrolyte, which is in a rectangular bath of uniform cross-section and having a graduated scale along its edge. Two movable electrodes connected up to a battery and galvanometer are dipped into the liquid so that the current shall oppose that from the main battery and are moved together or apart till null effect is observed on the galvanometer; the resistance of the length of column can then be determined from the known values of currents and of e.m.f. of auxiliary battery. Another method which has been very successfully applied is the Stroud and Henderson method, in which two horizontal tubes containing the electrolyte, equal in cross-section but of different lengths, and having similar electrodes, are placed in adjacent arms of a Wheatstone bridge and balance obtained with equal currents in the two arms, so that the polarisation effect is eliminated. The Kohlrausch method is well known.—**J. Wright,** *Electrical Review, Jan. 2, 1903,* pp. 3-5.—*H.*

The Storage Battery as a Factor in Speed-control.

THIS paper gives a description of the use of storage batteries as auxiliary or independent sources of supply in connection with the operation of printing presses, and with the multiple voltage system. The advantages are that (1) one battery will do for a number of presses, as all the presses in any establishment are not simultaneously at work; (2) the battery may be on charge at a very low rate at all times when current is flowing on the mains, thus giving the best possible results at minimum cost for current; (3) the battery has no moving parts to get out of order, and this appeals to the operators; (4) there is no variation of voltage, as in the case of a line supply. With multi-voltage generators the high prime cost of the battery does not exclude it from competitive consideration, as its higher efficiency helps to counteract the original extra cost.—**H. B. Coho,** *Trans. Amer. Inst. E. E., Dec. 1902,* pp. 1561-1564.—*H.*

TRACTION.

A Single-phase Electric Railway.

THE new railroad between Washington and Baltimore is about 31 miles long with a branch, 15 miles long, to Annapolis. The overhead trolley will be used, and speeds of over 40 miles an hour are to be attained. This railway is to exemplify the first commercial application of an entirely new system of electric traction, the special feature of which is the use of single-phase alternating current in generators, transmission lines, trolleys, car equipment

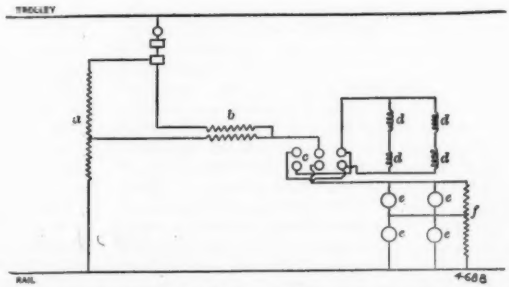


FIG 1.—*a* Auto-Transformer *b.* Induction Regulator *c* Reversing Switch *d* Field of Motors. *e.* Armature of Motors *f.* Equalizing Transformer

SINGLE-PHASE ELECTRIC RAILWAY.

and motors. After discussing the essential features of the direct-current railway system the author says, that it is not to the direct current that credit should be given for the great success of the present railway system, but to the series type of motor and the fact that up to the present time no suitable single-phase alternating-current motor has been presented. He then proceeds to point out some of the undesirable features and limitations of the direct-current systems, and adds that an alternating-current railway system should possess a single-supply circuit and the variable field motor, and must be single-phase if the more important disadvantages of the present direct-current railway apparatus are to be avoided. On the new railway, single-phase alternating current will be supplied to the cars at a frequency of $16\frac{2}{3}$ cycles per second, or 2,000 alternations per minute. The current from the overhead trolley wire is normally fed in by one trolley at approximately 1,000 volts. Within the limits of the District of Columbia two trolleys are employed, as by Act of Congress the use of rails as conductors is prohibited. The alternating current to the cars is carried through a main switch to an auto-transformer. For starting and controlling the speed an induction regulator is used, and the range of voltage at the motor is to be varied from 200 to 400 volts. Each car will be furnished with four 100-h.p. motors arranged in two pairs each consisting of two armatures in series and two fields in series, while the two pairs will be connected in parallel. Each motor has eight poles, and the speed is approximately 700 revolutions per minute at 220 volts. The general arrangement is shown in Fig. 1. The guarantee contained in the contract is that the efficiency on the system shall be equal to that of the direct-current system with rotary convertor substations. There will be an air compressor on each car for supplying air to the brakes and for operating the driving mechanism of the controller. The generating station will contain three 1,500-kilo-watt single-phase alternators, two 100-kilo-watt exciters available for use as alternators for supplying current for lighting when the large generators are shut down at night, and a main switchboard comprising three generator panels, one load panel, and three feeder panels. There will be nine transformer substations distributed along the railway line. Each station will contain two 250-kilo-watt oil-cooled lowering transformers, supplying approximately 1,000 volts to the trolley system. Two transformers are used in each station so that in case of accident to one transformer the station will not be entirely crippled. On inter-urban long-distance lines, the high trolley voltage and the absence of converter substations are features in favour of the new system, and for heavy railroad traffic it possesses many recommendations. It allows efficient operation of large equipments at practically any speed and any torque, avoiding the controller troubles which are ever present with large direct-current equipments, and the use of high trolley voltage reduces the current to be collected. There are many arrangements and combinations of apparatus made possible by the use of alternating current in the car equipments which have not been mentioned. But enough has been said by the author to indicate the possibilities of this new system.—**B. G. Lamme,** *Am. I. E. E., Vol. XIX.*, pp. 1231-1246.

Virtual Grades for Freight Trains.

DURING the past year more than 3,000 mls. were run by the writer with a dynamometer on heavy freight trains loaded much beyond the rating for the ruling grade, to see what minor grades could be run with momentum, and where the "stalling" point was on those which could not be run. The dynamometer record was condensed and plotted on profile paper above the grade and alignment; speed, pull, grade, and curvature being thus shown, so that train resistance could be readily taken from the pull of the locomotive and compensated for change of speed or velocity head, grade, and curvature. The author gives a series of diagrams, based on his experiments, showing train resistance curves for heavy freights, locomotive tractive power curves, distances for various changes in velocity on various grades for a consolidation compound locomotive's hauling full rating. Experiments were made with a ten-wheel locomotive having large boiler power and big drivers, with the hope that this type would be better suited to operate momentum grades because of its higher efficiency at high speeds, but the results were rather disappointing. The ten-wheel locomotive holds speed better, but attains it less readily, and, in general, when running for an adverse grade from rest, reaches the foot of the grade at less speed than the "consolidation" type of engine. The railway engineer's almost universal disapproval of momentum grades is probably caused by the lack of an easily-worked method of defining the limits for their proper use, and the mistaken idea that their introduction will cause stalling from bad weather conditions or from the power being in bad condition. These adverse conditions apply with greater force to long-ruling grades than to the shorter steeper momentum grades, as adhesion and steaming power are

taxed more, or taxed longer, on the former grade, if the momentum grades are not the ruling grades under favourable conditions. In momentum grades part of the work is done by momentum, which is not affected by weather conditions. Grades out of a divisional point should be reduced to a somewhat lower grade than at the other points, as the first few miles a train is run after standing for some time show a very much higher resistance than the normal, especially in cold weather. On favourable divisions, the rating can be raised 50% for about 10% of the original construction cost by the proper introduction of momentum grades, and, incidentally, the rise and fall and curvature can be improved. These improvements may often postpone indefinitely the necessity for double-tracking. Because of fewer stops, momentum grades generally tax locomotive powers less on double-track lines.—**A. C. Dennis,** *Proc. Am. Soc. C.E., Vol. XXVIII, No. 9, Nov. 1902*, pp. 765–776.

Chilled Iron Car Wheels.

IT may be safely stated that good car-wheel iron will develop 50 to 150 per cent. greater tensile strength than ordinary cast-iron, and can be and is made to closely approximate the strength of puddled steel quoted by Mr. Kirkaldy at 62,720 lbs., as the result of many experiments, while the Institution of Civil Engineers gives the tensile strength of Bessemer steel as 76,653 lbs. To meet the constantly increasing demand for wheels which will carry at least double the maximum load permitted six years ago, the up-to-date car-wheel foundry has found it necessary to give particular attention to mixtures; to the grading and analysis of different irons used; to uniform shop practice; to careful inspection of the finished product, etc. Iron containing titanium is known to be of great value in car wheels, having the effect of hardening the treads, and strengthening all parts of the wheel, including the plates The real or imaginary difficulty of smelting titaniferous ore has prevented its general use up to the present time, but all the objections against such ores seem to have been destroyed one after the other. Experiments with the metal demonstrate that titanium in iron gives greater density to the metal, surprisingly increases transverse strength, and gives a harder chill or wearing quality in the wheel. This is no light statement when it is remembered that the tread, or wearing surface of a car wheel, is already harder than steel—in fact a rough section of chilled car-wheel iron will cut glass. The clearly demonstrated practicability of supplying in one casting a wheel with a hard tread for wear, and a soft hub for machine work, with strength only limited by the price which the purchasing agent is willing to pay for it, makes the chilled cast-iron wheel peculiarly suitable for carrying the heavy traffic of the future.—**C. V. Slocum,** *Procs. Railway Club of Pittsburg, Nov. 28, 1902.*

Bournemouth Tramways: Combined Conduit and Overhead System.

THE Bournemouth Corporation, in installing electric tramways, decided to adopt the overhead system for the more outlying portions of the town, but to use the slot-conduit system in the central or busier parts, and the cars have therefore to be adapted to run over both systems. This article describes the principal features of the conduit system adopted. The Corporation having received tenders, finally accepted that of Messrs. J. G. White & Co., Ltd., for a side slot system, as it had the advantage of exposing less iron on the street and presented a better appearance. The two conduits are located under the two inner rails, which are of a special section designed to form a combined slot and wheel rail. The width of slot is 1 in., this being the least permissible for the wheel flanges; but where the slot is deflected to the centre of the track at slot points and at junctions of the two systems, the width is only $\frac{3}{4}$ in., which is sufficient for the plough. The slot-rails are supported by cast-iron yokes, spaced every 3 ft. 9 ins. apart, and weighing 200 lbs. each. The conductor rails in the conduit have their centres $14\frac{3}{4}$ ins. below the surface of the slot-rail; they are each $3\frac{1}{2}$ ins. in height, and as the depth of the conduit is 2 ft. $0\frac{1}{2}$ in., this leaves 8 ins. clear under the conductor-bars to the bottom of the tube. There is no novelty in the insulators of the conductors, or in the bonds, but the type of joint for the slot-rails has not previously been used for slot-rail construction. The fish-plates are not alike on inside and outside of the slot-rail, the outer being of the type known as the "continuous-rail joint," which gives the necessary lateral stiffness at the joints where it is suspended. At points where the slot is diverted from side to centre of track special steel castings are used, which on one face form the slot passing from the side to the centre position, and also have a groove for the wheel rail in the same line with the old side position of the slot. The plough must then follow the deflection, while the wheels go straight on, guided by the flange on the opposite rail. Plates are given showing many of the interesting features of the system and some of the special work on the track. The plough apparatus is similar

to that already adopted in other conduit systems, and has already been frequently described. The conduit was laid first and the wheel rails afterwards, and a considerable amount of work was done on pipes, as it is intended to use wood-paving, and advantage was taken of the road being "up" to make all desirable changes once and for all.—**A. N. Connett,** *Tramway and Railway World, Jan. 15, 1903*, pp. 17-28.—*H.*

LIGHTING, HEATING, AND VENTILATING.

Distributed Lighting.

In a paper bearing this title, the author directs thought to the necessity of determining the conditions existing at the illuminated surfaces with which we are constantly concerned in daily life. No light may ever be used until it impinges upon something, for, unless interrupted, light will continue along a straight line indefinitely. Distributed sources of light and diffusing surface are always present in actual lighting. The increase of the illumination upon a lighted surface due to diffusion from reflecting surfaces near the source of light reaches a maximum represented by the expression $\frac{1^8}{1-f}$, where f represents the reflecting co-efficient and is the fraction showing the percentage of reflected to the incident light. If f equals 95 per cent. the multiplication would be twenty times. Some actual tests of this effect are needed, though reflection co-efficients have been measured. In consequence of this multiplying power, diffusing surfaces are therefore a positive aid in distributing illumination. The illumination apparent upon a surface is, according to Fechner's law, proportional to the logarithm of the actual lighting stimulus reflected from the surface. The distribution of illumination along a surface with reflecting power of f per cent., from a lamp of intensity I candle-power, located at a normal distance of h feet from the surface, throwing rays of light at angles θ with the surface, the rays reaching points x feet distant from the foot of the normal, is determined by the formula

$$e = \frac{f I \sin \theta}{h^2 + x^2}$$

"e" is to be measured in luxes or candle feet. It is therefore possible in some measure to calculate the distribution of lighting along an illuminated surface, though the problem becomes further complicated when a second reflecting surface is introduced, and it may be at present considered impracticable to determine with any fair degree of accuracy the actual illumination in a room. It seems, however, quite possible actually to measure this lighting effect, a fundamental law in this connection being that illuminations from independent sources may be arithmetically added to determine resultant illumination. Arc lamps for the lighting of country roads should be such as throw their light downward, whereas in the lighting of city streets, lined with buildings, such lamps should be used as will throw an amount of light on the walls for diffusion purposes as will not be objectionable to the occupants. Few attempts have been made to measure the illumination on a surface, the nearest approach to such a measurement having been made by Hutchinson in connection with the lighting of the Congressional Library at Washington. In addition to this case, there have been few instances where the amount of illumination on a surface has been measured or calculated, notable among which may be mentioned a test of the lighting of the streets of Paris.—**Douglas Burnett,** *Am. I. E. E., Fol. xix., No. 9, Nov. 1902*, pp. 1477-1482.

The Future of Coal Gas and Allied Illuminants.

Few of the great industries have undergone such radical changes in condition as have fallen to the lot of gas manufact re during the past 20 years, and the series of lectures, of which the first was delivered in November last, is intended to show how these changes have arisen, and the direction in which they tend, together with such side issues as must of necessity be satisfactorily settled before the gas manager can give his full adhesion to the altered state of things.—**Prof. Vivian B. Lewes** (*Cantor Lectures*), *Journal of the Society of Arts, Dec. 26, 1902*, pp. 106-114.

POWER AND TRANSMISSION.

Motor-driving for Machine Tools.

This is an abstract of a paper read by Mr. Charles Day before the New York Electrical Society, in which he considers all the matters which have to be taken into consideration to secure best economy in machine-tool operation, and gives special attention to the question of driving by electric motors. The great variation of speed which is required causes many difficulties, and makes the constant-speed motor, whose simplicity of character renders its use specially desirable, in many respects unsuitable for the work. The induction motor has also many shortcomings, especially in the matter

of control, which ought to be possible at all times from the place where the tool-operator is stationed while at work. The best solution is found in the variable-speed motor working on a four-wire system, as six different voltages can then be used, and further speed-regulation may be made by resistances. The range of motor-speed is a most important factor, as the first cost of the motor, the cost of the installation, and the efficiency of the plant are all dependent upon it. No fixed rules can be laid down, as each machine must be considered as a separate problem; but for general machine shopwork it has been found that a range of 4 to 1 to 6 to 1 adapts itself to all conditions fairly well. In every case, however, where old tools are being equipped a compromise must be made. It is difficult to figure out beforehand what economy will result from the adoption of motor-driving, as the actual conditions in each particular shop must be studied. Crane service alone may be ample reason for its adoption. In the shops of the Link-Belt Engineering Company an accurate record, extending over five years, gives the pound cost of machining, and shows, after allowing the men a decrease of 10 per cent. in time with the same wages per week, a clear saving of 30 per cent. on the whole labour bill. Of course, in considering such figures as these, the effect of high organisation and improved management must always be kept in mind. The paper contains several drawings and charts, notably one indicating in diagrammatic form the principal advantages of the various methods that may be adopted for driving machine tools by electric motors.—**C. Day,** *Electrical World* (*N.Y.*), *Jan. 10, 1903*, pp. 78-80.—*H.*

TOOLS AND WORKSHOP PRACTICE.

The Idle Stroke of the Planer.

WHILE not disparaging any legitimate means of increasing the output of work, the writer is nevertheless under the impression that by the adoption of the extraordinary quick return motions found in some modern machines, the accruing advantages are not necessarily so great as may appear at first thought. In order that the actual improvement effected by the adoption of these comparatively abnormally quick returns may be traced, he tabulates the results of a comparison between various relations of cutting and return strokes, taking as a basis a cutting stroke of one minute's duration. The appended table shows the saving of time due to augmentations of the idle stroke of the planer, the cutting stroke being considered equal to 1.

—	Ratio of Return to Forward Stroke.	Saving over No. 1. Minutes.	(*a*) Saving over No. 1. %	(*b*) Saving over No. 2. %	(*c*) Saving over No. 5. %
1	1 :1	0	—	—	—
2	2 :1	½	25	—	—
3	2½:1	⅔	30	6⅔	—
4	3 :1	¾	33⅓	11⅑	—
5	4 :1	⅘	37½	16⅔	—
6	8 :1	⅞	43¾	25	10
7	12 :1	1 1/12	45⅝	27⅞	13½

After pointing out that augmentation of economy is in an inverse ratio with the increased speed of the return stroke, the writer says that if distinctly large gains be claimed as resulting from the employment of any machine, that saving is *not* so much the outcome of speeding up of the return stroke, but rather to the introduction of new features in design, rendering it possible to take deeper cuts and quicker feeds than on the machines of earlier design. What appears to be required for increasing the output of the planing machine is a means of varying the cutting speeds to suit the work in hand, rather than an increase in the return motion of the table. Often the cutting speed might be increased to 25 ft., 30 ft., and even to 40 ft. per minute. Obviously, then, if the machine be arranged to give varying forward speeds of 15 ft. to 40 ft. per minute, it is impossible to employ a constant ratio of return to forward speeds. It appears to the writer that the ultimate solution of the problem may be to drive from a countershaft, arranged to give varying speeds to the forward motion pulley and from a constant speed shaft (say the main shaft) to the return stroke pulley, the back stroke to be as rapid as is possible having regard to the construction of the machine.—*Am. Mach., Dec. 27, 1902*, pp. 865E-866E.

Worm Gearing

THE old opinion that the friction and wear of worm gears are necessarily very great, and that the efficiency is necessarily very low, making worm gearing an unmechanical contrivance, is no longer met with. In various writings on the subject, one important function of worm gearing is not brought out. This is the property a worm gear possesses, under certain conditions as to its design, of being self-locking and preventing motion backwards. An instance where this property becomes of prime importance and accounts

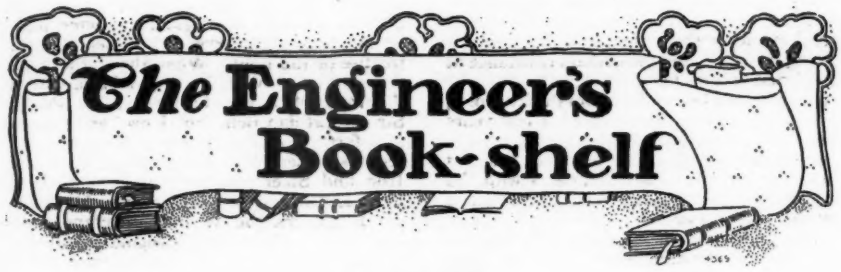
for the use of worm gear is in crane work, where the winding drum is driven by a worm gear so designed that when the power is shut off the gear will not run down or backwards under the impulse of the load, but will be self-locking, holding the load at any point. Taking the case of a single-thread worm in mesh with a worm wheel, it is necessary, in order that the system may be self-locking, that the tangent of the angle of the worm thread with the axis of the worm wheel must be less than the co-efficient of friction between the teeth of the worm and wheel. In all worm gearing there is a very heavy end thrust on the worm shaft, and also an outward force normal to the worm axis, each of which must be suitably provided for in the design of the shaft and bearings. The end thrust may be taken by bronze washers slipped into the bearings at the end of the shaft, which may be removed when worn and replaced with new ones. Shoulders may be provided on the shaft, between which and the bearings bronze collars may be placed, these being split to enable new ones to be easily and quickly placed in position when the old ones become worn. Roller thrust bearings are very often applied to worms, and these, as well as the bronze washers, may be supplied with adjusting set-screws to take up wear instead of renewing the washers. A worm gear of large pitch will require a pitch diameter of the worm altogether too large for practice if it is to be self-locking, and as usually designed the system may be expected to run backwards. To prevent this, a friction disc may be placed in the bearing which receives the thrust of the worm shaft when the system is running backwards, and the diameter of the disc may be so proportioned as to just hold the worm shaft stationary under the impulse of the worm wheel. Friction naturally varies with various types of bearings, and the frictional resistances developed by the journals act in a direction helpful to the self-locking property of the worm. But it is evident that when running forward the end thrust upon the worm shaft will be upon the opposite end from that when running backwards, and on this account a system may be designed to have a high efficiency on the forward movement and still preserve its self-locking property. If the end taking the thrust on the forward movement be fitted with ball-bearings, and the opposite end be made with ordinary bearings, the worm may be designed to show a very high efficiency on the forward movement, while the frictional resistance at the opposite end will cause the system to be self-locking by reason of the energy absorbed at the step bearing. The author gives several formulas which may be applied to various cases arising in the design of self-locking worm gear.—**C. F. Blake,** *Machinery, Dec. 1902*, pp. 189-191.

MISCELLANEOUS.

Steel Ball-Bearings.

RESULTS of high theoretical and practical importance were arrived at by some remarkable investigations on ball-bearings by Professor Stribeck. These researches have received both a confirmation and an extension by Dr. Heerwagen, for some time engineer to the Horcajo lead mines in Spain, where ball-bearings have been adopted for the new electrically-driven centrifugal pumps, constructed by Messrs. Sulzer Bros., Winterthur. The object of the theoretical deductions to which reference is made was to ascertain the distribution of the load upon the different balls of a bearing under the assumption of some very slight constructional defect, and to lay down practical rules for the designer. Like Prof. Stribeck, Dr. Heerwagen based his investigation on the researches of Heinrich Hertz, and a full account of his mathematical deductions will be found in the *Zeitschrift des Vereine Deutscher Ingenieure* of November 30, 1901, p. 1701. Having explained at some length the further development of the theory of ball-bearings which Dr. Heerwagen deduced from Hertz's formula, the writer proceeds to describe and illustrate some forms of bearings made by the Deutsche Waffen-und-Munitions-Fabriken, of Berlin. These bearings have passed the trial stage and have been applied to pedestal and bracket bearings, to cranes, vehicles of all kinds, particularly to automobiles, to railway cars, to dynamos and motors, to centrifugal pumps, and other machinery for heavy loads and speeds up to 3,000 revolutions per minute. The normal bearings consist of two concentric collars of hardened steel, well polished on the inside and ground on the face, the balls being also of hard steel, ground and carefully polished. A locking-piece, held by a screw to one collar, provides for removal of the balls when required.—*Engineering, Dec. 26, 1902*, pp. 833-36.

Most of the publications referred to can be obtained on application to Messrs. Williams & Norgate, Henrietta Street, Covent Garden, London, W.C. A full list of the papers regularly abstracted and prices will be given in the next issue.



Practical Calculation of Dynamo-Electric Machines.—By A. E. Wiener. Second Edition. *Electrical World and Engineer*, New York. xxxvi and 727 pages. Price 3 dollars. 1902.

This is a comprehensive work consisting essentially of a collection of data, tabular and otherwise, for the design of dynamo-electric machinery. It is a work which should be of considerable assistance to the practical dynamo designer, and also, though in a lesser degree, to the student. We cannot, however, endorse the extraordinary claim made by the author in his preface, that "anyone possessing a but fundamental knowledge of arithmetic and algebra will by means of this work be able to successfully calculate and design any kind of continuous-current dynamo," in other words that the study of this work will afford a satisfactory substitute for practical experience.

Assuming that every table in the book were without error or mistake of any kind, and that all the explanations were so clearly expressed that the veriest tyro could not by any possibility misunderstand them, such a claim would be absurd.

Even if all the conditions to be complied with were duly set forth, and the supposedly perfect data ready to hand, much more would be required to enable the would-be designer to produce the plans of a machine which would have any prospect of commercial success.

The successful design of a dynamo involves not merely the knowledge of the physical properties of materials, and of the manner of combining them to produce predetermined mechanical and electrical results. Another and no less important requisite is an intimate knowledge of cost of construction as depending on the price of material, on the cost of labour, on the nature of the tools available, and other details, such, for example, as the designing of the foundry patterns in such a manner as to obtain mechanically satisfactory castings with the minimum expenditure on labour and material.

In thus criticising a foolish and unwarrantable claim, it is only just to the author to point out that this criticism is not to be taken as in any way depreciating the value of a work which contains an enormous amount of carefully selected and well-arranged data. The dynamo designer who has obtained the familiarity with the requirements of commercial practice requisite to entitle him to the appellation will here find ready to his hand, data which he would otherwise have to collect with much labour from many scattered sources.

The work is divided into eight sections. The first of these consists of a brief sketch of the physical principles which underlie the construction and operation of dynamo machinery. It is preceded by a very useful list of all the symbols used throughout the work and their signification. The second section, on "Armature Calculations," is one of the most valuable portions of the work, the figures given being all taken from actual practice. On page 63 the author makes the statement that in the case of machines in which large currents are commutated at low voltages, and where the commutation is required to be sparkless, without shifting the brushes for varying loads, "the disadvantage of increased self-induction in the toothed armature is the main consideration, and drives it out of competition with the smooth armature." This is a somewhat sweeping statement, and, to say the least, is not in accordance with present Continental opinions and practice. The question of sparkless commutation is far too superficially treated, considering the great importance of the subject. Moreover, the figures given are only applicable to

smooth cored armatures with copper brushes, no tables being given for the cases of carbon brushes and toothed armatures. On page 179 the figures given for the contact resistance at the brushes are far too high, and would appear to have been taken from Buck's tables, which were commonly accepted a few years ago. According to Dettmar's recent investigations, the values given should be reduced to about one-half. Part III. deals with the calculation of magnetic flux, and contains much valuable matter.

The fourth section is devoted to the consideration of the dimensions of field-magnet frames, and would have had its value greatly increased if a clear distinction were drawn between obsolete forms and those employed in present practice. One wonders, too, why the magnet frames of enclosed motors find no place in this section. We may note that the grouping of magnetic circuits given on pages 353 and 354, and the diagrams on the latter page, are extremely helpful. Sections 5, 6 and 7 are devoted to the calculation of magnetising force, magnet windings, efficiency, designing a number of dynamos of the same type, the calculation of electric motors (including railway motors), motor-generators, some special types of dynamos, and a chapter on graphics as applied to dynamo calculation.

The eighth and concluding section, containing some 150 pages, is devoted to worked-out examples, and in our opinion is unnecessarily long, as the examples are all based on the data given in the earlier portions of the volume and do not introduce any new matter.

Three appendices bring the volume to a conclusion—(1) tables of dimensions of modern dynamos; (2) wire tables and winding data; (3) the localisation and remedy of troubles in dynamos and motors in operation. A very valuable feature of the book is the copiousness of the references to original papers.

Various standard works are also frequently referred to for further information on the theory of the subject. There is also a copious index, which is an absolute necessity in a work of this character.

The Metallurgy of Iron and Steel. By A. Humboldt Sexton. (Manchester: The Scientific Publishing Co., 1902.) 16*s*.

To everyone who requires a complete guide in a compact form to the metallurgy of iron and steel, we heartily recommend the work recently written by Professor Sexton. As the author admits, there is little in his work of original character, and, in fact, originality would be useless in a treatise of the kind. What the author has done, and done well, is to quote largely from the works of such authorities as Dr. Percy, Sir I. Lowthian Bell, Prof. Howe, and others, and, further, he has drawn freely upon the records presented by the Transactions of the Iron and Steel Institute, the Institution of Civil Engineers, the Institution of Mechanical Engineers, the West of Scotland Iron and Steel Institute, the Cleveland Institution of Engineers, the North Staffordshire Institute of Iron and Steel Works' Managers, the American Institute of Mining Engineers, as well as from leading technical journals. From this statement it must be evident that Professor Sexton has looked in the right direction for reliable information, and the manner in which the result of his research is presented leaves little to be desired. The book is admirably arranged, illustrated with some 200 blocks; and of three appendices, those devoted to the Nomenclature and Bibliography of Metallurgy are distinctly valuable. In concluding this brief notice we must pay a tribute to the publishers for the excellent manner in which the work has been produced.

Modern Foundry Practice.—Part I. By Geo. R. Bale, A.M.Inst.C.E. (London: The Technical Publishing Co., Ltd., 1902.) Price 5*s*.

A reliable guide to modern foundry practice has certainly been wanted for some time; the old order of things in this department of engineering work is passing away, and the scientific founder is beginning to replace his predecessor who relied largely on rule-of-thumb methods and rules. Nevertheless, progress in the foundry has hardly kept pace with the advances generally manifest in the iron and steel industry, and we hope that the manual, of which the first part is now before us, may exercise a beneficial influence. It deals with all classes of work to be performed in the foundry, from cupola practice to moulding, and it is illustrated with a large number of excellent woodcuts. The second part promised by the author is to include the consideration of machine moulding, shrinkage, distortion, and the various methods adopted for cleaning castings. These parts of the subject are of extreme importance, and it may be hoped that the second volume will be issued with the least possible delay.